THE NICKEL BULLETIN

A MONTHLY SUMMARY OF CURRENT INFORMATION

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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Thermal Conductivity of Metallic Materials at Elevated Temperatures

R. D. SEIBEL: 'Survey and Bibliography on the Determination of Thermal Conductivity of Metals at Elevated Temperatures.'

Watertown Arsenal Laboratory Report No. WAL 821/9 (P.B. 111756) Aug. 15, 1954; 65 pp.

The investigation reported was initiated to survey the existing methods of measuring thermal conductivity, with a view to selecting the one best suited for use in the Watertown Arsenal Laboratory. A brief outline is given of the principles and techniques of all the major methods of measurement at present in use: their relative advantages and disadvantages are considered. A *bibliography* of 300 references to the literature supports this discussion, and a list of 30 items dealing with thermal conductivity at very low temperatures is also included.

As a result of the wide survey of methods available for study of thermal conductivity of heat-resistant materials, a modified form of the Forbes bar method was selected for use in the Watertown tests, of which the results are embodied in the report. A series of graphs show thermal conductivity, as a function of temperature (over various elevated ranges), for typical carbon, chromium, nickel, austenitic chromium-nickel, and complex alloy steels; commercial nickel; alloys of nickel with chromium and/or iron; complex nickel-base heat-resisting alloys containing varying amounts of chromium, cobalt, iron, molybdenum and other elements; titanium; Stellite (cobalt-base) alloys; tungsten, and molybdenum. The value of the report is considerably enhanced by addition of a subject index.

Nickel-containing Materials in Bourdon Pressure Gauges

C. F. BUDENBERG: 'The Bourdon Pressure Gauge.' *Trans. Soc. Instrument Technology*, 1956, vol. 8, June, pp. 75–88.

This paper presents a summary of information to be used as reference material for those responsible for the selection, installation or maintenance of Bourdon pressure gauges.

A brief account is given of the invention of the Bourdon model, and its design, installation, maintenance, adjustment and testing are discussed, with a table showing the composition, treatment and characteristics of typical tube materials. Reference is made, *inter alia*, to the use of K Monel (nickel-copper alloy containing aluminium), stainless nickel-chromium-molybdenum steel, and Ni-span C (nickel-iron base alloy containing chromium and titanium).

Effects of Irradiation on Nickel-containing Materials

F. E. FARIS: 'The Effects of Irradiation on Structural Materials.'

Proc. International Conference on the Peaceful Uses of Atomic Energy, 1955, vol. 7, pp. 484-9. Published by *United Nations, New York*, 1956.

The purpose of this paper is to provide a survey of investigations which have been carried out on this subject in the U.S.A. In order to keep the length of the paper within reasonable limits, the author has presented typical data rather than an exhaustive summary of available information.

Following a condensed review of general changes in the physical properties of metallic materials resulting from irradiation, specific reference is made to its influence on:—

Hardness (beryllium, molybdenum, nickel, austenitic stainless steel).

Creep (aluminium, nickel, zirconium, Constantan, Inconel, austenitic stainless steel).

Impact Strength (pressure-vessel steel, molybdenum, zirconium).

Phase Transition (iron-copper alloys, austenitic stainless steel).

Diffusion (copper-gold and copper-nickel alloys and austenitic stainless steel-U^{235}).

S. T. KONOBEEVSKY, N. F. PRAVDYUK and V. I. KUTAITSEV: 'The Effect of Irradiation on the Structure and Properties of Structural Materials', pp. 479-83.

This paper gives an account of research on the specific nature of hardening and other changes in properties and structure of metals and alloys caused by irradiation. The materials for which hardness, mechanical properties and microstructural changes are recorded include copper, nickel, and Armco iron, zirconium, and a series of typical austenitic, martensitic, pearlitic and ferritic steels.

Cleaning of Radio-Contaminated Metals

J. B. HUFF: 'Electrodecontamination of Metals.' *Nucleonics*, 1956, vol. 14, June, pp. 70, 73–7.

A process normally used for electrocleaning steel in alkaline solutions has been found satisfactory, with some modifications, for decontamination of irradiated metals from reactors. The essential features of the process are as follows:—

The item to be decontaminated is suspended by an insulated link in a stainless-steel kettle of near-boiling sodium-hydroxide solution, and the work is made anodic by connecting it to the positive side of a high-amperage source of direct current. The stainless-steel kettle is used as the other electrode.

High average current densities are used, because evolution of oxygen from all surfaces is desirable.

In the early work on this project the electrolyte used was sodium-hydroxide solution made up at a concentration of 6 ounces of flake sodium hydroxide per gallon of water. This solution gave good results, but the bursting of bubbles threw drops of caustic into the air. By adding one ounce per gallon of laboratory Calgonite (glassy sodium phosphate) a foam is produced on the surface of the solution, and hardly any airborne caustic is noticed during electrolysis. Good foaming characteristics are obtained with a solution containing sodium hydroxide 4, sodium carbonate 2, trisodium phosphate 2, ounces per gallon of water. It is noted that higher concentrations of alkali might be required for removing heavy deposits of paint or grease.

After 1-3 minutes' treatment in this solution the item is removed and rinsed in water. Wire brushing with the alkaline solution may be required at this stage, especially if paint is being removed. The work is then dipped in 2*N* sulphuric acid, and may be made anodic at a low current density. Smut may appear on the surface at this stage, and it apparently carries radioactive particles, but most of it may be removed by wire brushing the acid-wet surface. The work is then rinsed in water and dried with rag or tissue.

The nature of the contaminant to be removed, and the practical operation of the cleaning method, are described in detail. Most of the experience with this process has been in decontamination of stainless and carbon steels, since these are the materials most generally employed in nuclear plant. No particular study has been made of its applicability to decontamination of copper, brass or aluminium, although components of these metals have been put through the process as parts of assembled machines. Aluminium reacts with the alkali, but on most parts some etching can be tolerated.

The article includes a description of the decontamination room in which this process is operated.

Effect of Test Specimen on High-Temperature Mechanical Properties

See abstract on p. 176.

NICKEL

Self Diffusion in Nickel

R. E. HOFFMAN, F. W. PIKUS and R. A. WARD: 'Self-Diffusion in Solid Nickel.'

Jnl. of Metals, 1956, vol. 8, May, Pt. II; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 483-6. T.P. 4087 E.

The self-diffusion coefficient of high-purity nickel was measured over the temperature range 870°-1248°C. It was found that the measured activation energy correlates satisfactorily with absolute melting point, heat of fusion and heat of sublimation.

Diffusion of Other Elements in Nickel

R. A. SWALIN and A. MARTIN: 'Solute Diffusion in Nickel-base Substitutional Solid Solutions.'

Jnl. of Metals, 1956, vol. 8, May, Pt. II; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 567-72. T.P. 4147 E.

Diffusion rates of manganese, aluminium, titanium and tungsten in nickel were measured at temperatures between 1100° and 1300°C. Activation energies, Q, were found to be within 15 per cent. of that for self diffusion of nickel, a finding which is in agreement with current theories of diffusion. The diffusion coefficients of manganese in an alloy of nickel containing 5 per cent. titanium were also determined: manganese diffuses in this alloy at the same rate as in pure nickel.

Influence of Compression on Magnetic Properties of Nickel and Nickel Alloys

F. D. STACEY: 'The Behaviour of Ferromagnetics under Strong Compression.'

Canad. Jnl. Physics, 1956, vol. 34, pp. 304-11.

Specimens in the form of thin discs were subjected to various degrees of compression while under the influence of high magnetic fields. A new design of permeameter, used to investigate the magnetization effects so produced, is described and illustrated. Magnetization curves extending to saturation were plotted, at (non-hydrostatic) pressures up to 10,000 atmospheres, for the following materials:—nickel, nickel-copper alloys containing up to 25 per cent. and 29-33·5 per cent. of copper, iron, cobalt, Monel, Brightray C (80-20 nickel-chromium alloy*), Nilo 36 (nickel 36, iron 64, per cent.), and austenitic chromium-nickel steels.

The most interesting result is the strong increase in saturation magnetization shown by nickel under compression and by the nickel-copper alloys containing up to about 25 per cent. of copper. The effect of compression on iron in low fields is strongly dependent on carbon content and on thermal history. Cobalt is very little affected by pressure, and Monel and Brightray C are negligibly affected, but in the nickel-iron alloy compression resulted in a strong decrease in magnetization in all fields. Austenitic steels containing chromium 18, nickel 6, iron 76, per cent. approx., which are only slightly magnetic, showed a tendency for magnetization to decrease with pressure.

Thermal Conductivity of Metallic Materials at Elevated Temperatures

See abstract on p. 156.

Reflectivity of Nickel and Other Metals

D. HEINZE: 'Reflectivity Characteristics of Copper, Silver, Gold, Aluminium and Nickel as a Function of Temperature.'

Zeitsch. Physik, 1956, vol. 144, pp. 455-75.

Study of reflectivity in the visible range, at temperatures between −150° and +100°C. In the

** Erroneously described in the original as 80-20 nickel-cobalt alloy.*

case of nickel variation in temperature had no effect on reflectivity.

Spectral Emissivity of Nickel

L. WARD: 'The Variation with Temperature of the Spectral Emissivities of Iron, Nickel and Cobalt.'
Proc. Physical Soc., Sect. B, 1956, vol. 69, Mar. 1, pp. 339–43.

The spectral emissivities of iron, nickel and cobalt were measured over a wavelength range 1·0 μ to 3·0 μ and at temperatures between 650° and 1350°C. The results show anomalies in iron and cobalt, occurring at temperatures in the neighbourhood of the respective Curie points. Tables of the temperature coefficients of emissivity for the three metals are given.

Corrosion of Nickel by Surface-Active Agents

H. HOLNESS and R. D. LANGSTAFF: 'Studies in the Corrosion of Metals Occasioned by Aqueous Solutions of Some Surface-Active Agents: V. Nickel.'
Jnl. Applied Chemistry, 1956, vol. 6, Apr., pp. 140–1.

The action of dilute aqueous solutions of anionic non-ionic, and cationic surface-active agents on nickel foil was studied. Nickel was shown to be resistant to attack by anionic agents. One cationic agent, cetylpyridinium bromide, in distilled water solution, corroded the metal, but other cationic and non-ionic agents were almost without effect.

Resistance of Nickel to Corrosion by Fused Caustic

See abstract on p. 173.

Corrosion of Nickel Welds in Caustic Solutions

See abstract on p. 174.

Sublimation Figures in Nickel and Other Metals

J. C. DANKO and A. J. GRIEST: 'Sublimation Figures in Nickel, Copper and Zinc.'
Jnl. of Metals, 1956, vol. 8, May, Pt. II; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 515–16. T.N. 293 E.

A short note comprising a theoretical discussion on sublimation figures observed on the surface of pure nickel specimens in the course of vacuum-evaporation experiments.

Comparison is made with similar sublimation figures observed on copper and zinc, but this feature was not observed on iron. A mechanism of formation of the figures is proposed.

Effects of Irradiation on Nickel-containing Materials

See abstract on p. 156.

Emission of Gas from Nickel-Alkaline Accumulators

P. H. HODSON and H. TITMAN: 'The Emission of Gas from Alkaline Cells.'
Ministry of Fuel and Power, Safety in Mines Research Establishment, Research Report No. 121, Oct., 1955; 19 pp. Price 1s. 3d.

The rate of emission of gas from lead-acid accumulators, and the effect of various factors on the rate of emission, have already been established, and the results have been published. Alkaline (nickel-iron and nickel-cadmium) batteries are capable of withstanding more rough usage, both mechanical and electrical, than the lead-acid type, and they are now used extensively for cap and hand lamps in mines. In connexion with the possible use of heavy-duty alkaline cells for battery-driven locomotives in mines it was necessary to investigate the evolution of gas from alkaline cells, in order to determine whether requirements of ventilation for the containers of lead-acid batteries, as specified in the Ministry of Fuel and Power Testing Memorandum, would be adequate for alkaline batteries.

In the experiments described, carried out on six heavy-duty Nife batteries, a study was made of the composition and rate of evolution of gas during discharge or on standing after charging. It was found that the composition of the gas varied throughout the period of discharge: the hydrogen content was never less than 20 per cent. and rose to over 90 per cent. towards the end of the discharge. Gas was emitted vigorously immediately after charging, for a period of at least 90 minutes. During a period of intermittent discharge and rest immediately after charging the rate of emission of gas during discharge was about half that during standing. The age of the cell did not affect the rate of emission of gas, either during standing or normal discharge, and the strength of the electrolyte was also without influence. When old and new cells were coupled together in one battery and current was drawn from them, the old cells gassed vigorously when they became exhausted. No trace of pyrophoric iron was detected in the spray above the electrolyte in the cell tops.

Nickel-Cadmium Accumulators in Signalling Lamps

'Signalling Lamp Batteries.'
Engineer, 1956, vol. 202, July 6, p. 34.

The Ministry of Transport and Civil Aviation has now approved the use of the Nife nickel-cadmium alkaline battery to power the 60W Mark X Aldis lamp. The alkaline cells, for an almost identical burden on the signaller give about ten times longer life between charges than is obtained from lead-acid accumulators and they are less affected by rough handling.

Nickel Electrodes in Fuel Cells

F. T. BACON and J. S. FORREST: 'High-Pressure Hydrogen-Oxygen Fuel Cell.'
Engineer, 1956, vol. 202, July 20, pp. 93-4.

Section of paper entitled 'Recent Research in Great Britain on Fuel Cells' presented (as communication 119 K/4) to the Fifth World Power Conference, 1956. The original paper reviews various kinds of fuel cells which are now being investigated: the abstract relates only to the hydrogen-oxygen cell.

The principles of operation of this type are discussed and its mode of operation is described in some detail. Development is traced from the work of Grove

in 1839, through that of Mond and Langer some 50 years later, up to research recently carried out in the Central Electricity Authority's laboratory at Leatherhead, and in the University of Cambridge, under the auspices of the Electrical Research Association and the Ministry of Fuel and Power.

Several different kinds of cell have been tried, leading up to the development of the present design, which is illustrated in this paper. The electrodes are of porous sintered nickel and the main parts of the cell are of nickel-plated steel or pure nickel. The electrolyte is strong caustic potash solution. Normal operating conditions are 200°-240°C. and 42-56 kg./cm².

Among the problems encountered in development was the gradual oxidation of the oxygen electrode, leading to a drop in output and ultimately to complete breakdown. This deterioration has now, to a large extent, been prevented by using a pre-oxidation treatment at a high temperature in air before inserting the electrode into the cell. Lithium atoms are incorporated into the crystal lattice of the oxide, thus converting the ordinary green oxide, which is an insulator, into a black double oxide of nickel and lithium, which is a moderately good semiconductor. Using this technique it has been possible to obtain an oxygen-electrode service life up to 1,500 hours at 200°C. Other improvements recently introduced are also described in this abstract.

The probable advantages of the hydrogen-oxygen cell are briefly summarized.

Nickel Diffusion Leaks

L. C. W. HOBBIS and E. R. HARRISON: 'Use of Nickel Diffusion Tubes for the Purification of Hydrogen.'
Rev. Scientific Instruments, 1956, vol. 27, Apr., p. 238.

Further to the paper published *ibid.*, 1955, vol. 26, pp. 305-6, the authors advance additional arguments in favour of the suitability of nickel for the above purpose.

E. R. HARRISON and L. C. W. HOBBIS: 'Nickel Diffusion Leak for Hydrogen: Addendum.'
Ibid, 1956, vol. 27, May, p. 332.

This note gives additional information which has been obtained during the use of the leak and the authors make recommendations as to operating conditions.

Nickel and Monel Equipment in Fluorine Production

See abstract on p. 175.

Nickel-Oxide Catalysts

T. J. GRAY and P. W. DARBY: 'Semi-Conductivity and Catalysis in the Nickel-Oxide System.'
Jnl. Physical Chemistry, 1956, vol. 60, Feb., pp. 209-17.

The work described was carried out with the object of correlating changes in electrical conductivity during adsorption and desorption of various gases on nickel oxide with the kinetic processes involved. The results permit development of a model for the catalyst surface which satisfactorily accounts for its known properties.

Analysis of Nickel for Electronic Use

AMER. SOC. TESTING MATERIALS: 'Proposed Revision of Tentative Photometric Methods for Chemical Analysis of Electronic Nickel' (E.107-54T).
A.S.T.M. Preprint 57a, June, 1956, pp. 18-33.

The essential features of the methods recommended are briefly indicated below:—

Aluminium (by the Aluminon Method)

After removal of interfering elements by mercury-cathode separation and cupferron-chloroform extraction, aluminium is determined photometrically by the aluminon method.

Carbon

The method is based on the combustion of the sample in oxygen at low pressure, freezing the carbon dioxide, and measuring it in the gas phase and in a known volume, by means of a McLeod gauge.

Hydrogen, Nitrogen and Oxygen by the Vacuum-Fusion Method

The procedure is based on fusion of the metal in the presence of carbon in a vacuum. Under these conditions all oxides present are reduced to carbon monoxide, and nitrogen and hydrogen are liberated. The gases evolved are collected and analysed by low-pressure techniques. Hydrogen is oxidized to water and is absorbed in anhydrous magnesium perchlorate. The carbon monoxide is converted to carbon dioxide and frozen out in liquid nitrogen. The residual gas is nitrogen.

Titration of Nickel with E.D.T.A.

R. TER HAAR and J. BAZEN: 'The Titration of Nickel with E.D.T.A. at pH 2·8.'
Analytica Chimica Acta, 1956, vol. 14, May, pp. 409-13.

In the method described a small excess of E.D.T.A. is added to a nickel-containing solution, the pH is adjusted to 2·7-2·9, and the solution is back-titrated with thorium nitrate, against alizarin-S as indicator. The procedure permits determination of nickel in the presence of cobalt.

Determination of Small Amounts of Nickel with α-Furildioxime

C. G. TAYLOR: 'Determination of Small Quantities of Nickel with α-Furildioxime.'
Analyst, 1956, vol. 81, June, pp. 369-71.

The work described, which was carried out under the auspices of the United Kingdom Atomic Energy Authority, resulted in development of a sensitive and robust method for estimation of nickel at the 1 to 10 μg level. A study was made of the interference resulting from iron, chromium, or alkali-metal salts, and the application of the procedure to the determination of nickel in plutonium solutions is described.

Determination of Trace Amounts of Nickel

H. W. H. ADDINK: 'Determination of Trace Elements (without Chemical Pretreatment) and Analysis of Trace Quantities by Spectrochemical Procedures.'
Mikrochimica Acta, 1956, pp. 299–303.

Limits of identification and suitable wave lengths are given for nickel and 34 other elements.

Photometric Determination of Nickel

W. NIELSCH and L. GIEFER: 'Photometric Determination of Nickel with Sodium Dimethylglyoxime.'
Mikrochimica Acta, 1956, pp. 522–7.

It is shown that very small quantities of nickel can be precipitated with the water-soluble salt of dimethylglyoxime. The nickel compound formed can be extracted with $CHCl_3$. Details are given of photometric conditions and the apparatus used.

A. T. BLACKWELL, A. M. DANIEL and J. D. MILLER: 'Photometric Determination of Nickel in Petroleum Cracking Catalyst.'
Analytical Chemistry, 1956, vol. 28, July, p. 1209.

Determination of nickel in petroleum cracking catalysts is of importance because nickel, a likely contaminant in oil-feed stocks, is a catalyst poison in this connexion. Procedures for the use of dimethylglyoxime in the photometric determination of nickel have been proposed, but the authors report that for estimation of the metal in petroleum-cracking catalysts they have had no success in applying published recommendations. They describe an improved method which, it is claimed, gives excellent reproducibility, is simple, and compares favourably in accuracy with the lengthy gravimetric procedure. The colour obtained is stable, and no precipitation of nickel occurs in the range up to 300 γ of nickel per gram of sample. Full details of procedure are given.

Diallyldithiocarbamido-Hydrazine in the Determination of Nickel

N. K. DUTT and K. P. SEN SARMA: 'Diallyldithiocarbamido-hydrazine as an Analytical Reagent.'
Analytical Chimica Acta, 1956, vol. 15, pp. 21–4.

Under controlled pH conditions diallyldithiocarbamido-hydrazine precipitates copper, nickel, zinc and lead quantitatively from their solutions. Copper is precipitated at pH 2·5–3·5, lead at 5–6, zinc at 7·5–8·6, and nickel at 8–9.

Determination of Nickel in Copper Salts

E. A. JOHNSON and E. J. NEWMAN: 'The Rapid Determination of Traces of Nickel in Copper Salts.'
Analyst, 1956, vol. 81, May, p. 318.

The method described is based on work by Johnson and Simmons (*ibid.*, 1946, vol. 71, p. 554), who employed nioxime as a colorimetric reagent for nickel. In the absence of a stabilizer the pink nickel-nioxime complex formed in aqueous ammoniacal solution is gradually deposited on standing, but if the solution is shaken with benzene the complex collects in the interface between the two layers. Copper forms a khaki-coloured complex, which is not removed from the aqueous layer in this way. Provided that enough nioxime is added to deal with all the copper and all the nickel, the nickel complex can be separated from the copper. A double extraction into benzene is recommended. If only one extraction is used, traces of copper are carried through the procedure and impart a slight yellowish hue to the pink solution obtained for the final comparison with standards. By the method recommended 0·005 mg. of nickel can be detected: this is equivalent to 0·02 per cent. in copper metal.

W. NIELSCH: 'Extraction and Determination of Small Quantities of Nickel Dimethylglyoxime with Chloroform. Application to the Determination of Nickel in Copper Salts.'
Zeitsch. analytische Chemie, 1956, vol. 150, pp. 114–18.

Full directions are given for determining 0·004 to 0·018 per cent. of nickel in a solution, and by suitable modification the directions given can be applied to estimation of both smaller and larger quantities. For essential details of the process see *Chemical Abstracts* 1956, vol. 50, July 10, p. 9217.

Determination of Nickel in Uranium and its Compounds

C. J. SAMBUCETTI, E. WITT and A. GORI: 'Polarographic Determination of Copper, Cadmium, Zinc, Nickel, Cobalt, Lead and Bismuth in Uranium and its Compounds.'
Proc. International Conference on the Peaceful Uses of Atomic Energy, 1956, vol. 8, pp. 266–70.
Published by *United Nations, New York*, 1956.

The joint deposition of the metals mentioned, by electrolysis with a mercury cathode, is used for ultimate polarographic determination of the individual elements.

Separation of Small Amounts of Nickel from Cobalt

I. P. ALIMARIN and V. V. LORENEVA: 'Separation of Small Amounts of Nickel from Cobalt by Extracting Nickel Salicylaldimine.'
Zavodskaya Lab., 1955, vol. 21, pp. 907–10.

For details of method see *Analytical Abstracts*, 1956, vol. 3, May, Abstract No. 1372.

Determination of Silicon in Nickel

W. GANN: 'Spectral Photometric Microdetermination of Silicon in Cathode Nickel.'
Zeitsch. analytische Chemie, 1956, vol. 150, pp. 254–62.

For particulars of process see *Chemical Abstracts* 1956, vol. 50, July 10, p. 9219.

Nickel Dermatitis

C. D. CALNAN and G. C. WELLS: 'Suspender Dermatitis and Nickel Sensitivity.'
Brit. Medical Jnl., 1956, June 2, pp. 1265–7.

Contact dermatitis in individuals allergic to nickel

is well recognized in industry, and due precautions are taken to protect any employees who may be susceptible. This article deals almost entirely with dermatitis occurring as a result of wearing, next to the skin, nickel-plated fasteners used on underwear, or jewellery in which nickel-containing materials are employed. It is suggested that any who may be allergic to this metal should wear only all-plastic or all-nylon suspender buckles and other fastenings.

Production of Cobalt-58 by Irradiation of Nickel

C. E. MELLISH and J. A. PAYNE: 'Production of Carrier-Free Cobalt-58 by Pile Irradiation of Nickel.'
Nature, 1956, vol. 178, Aug. 4, pp. 275-6.

In experiments at the United Kingdom Atomic Energy Research Establishment, Harwell, carrier-free cobalt-58 has been obtained as a result of irradiation of nickel under various conditions: yields are tabulated. The characteristics of the cobalt-58 produced under specific conditions are discussed.

ELECTRODEPOSITION AND OTHER COATING METHODS

Bright Nickel Plating: Solutions, Technique, Properties of Deposits

T. E. SUCH: 'Bright Nickel-Plating Solutions: Their Choice, Control and Operation.'
Mond Nickel Co., Ltd., Publn. 985,* 1956; 22 pp.

Reprint of paper abstracted in *Nickel Bulletin*, 1955, vol. 28, No. 12, p. 212.

Atmospheric Corrosion-Resistance of Nickel/Chromium Coatings

L. E. LANCY: 'New Angles on Plating Topics Revealed at A.S.T.M. Meeting.'
Electroplating and Metal Finishing, 1956, vol. 9, July, pp. 233-5.

During a symposium on 'Properties, Tests and Performance of Electrodeposited Metallic Coatings', held recently under the auspices of The American Society for Testing Materials, some information was given with regard to the behaviour of nickel/chromium coatings during atmospheric exposure tests carried out over a long period by the joint committee of The American Society for Testing Materials and The American Electroplaters' Society.

Although the full report of the symposium is not yet available, the following statement may be quoted as being of immediate practical importance:—

'MR. C. H. SAMPLE talked about the corrosion tests conducted on copper/nickel/chromium and nickel/chromium plating systems on steel. The atmospheric corrosion tests were started in 1949 and have been continuously expanded since then. The first results indicated that the copper undercoating does not add to the protective value of the finish. Later testing programmes, covering four coating-thickness ranges (1, 1·5, 2 and 3 mil.) and eight variations in the plating system, tended to confirm this finding. However, it came as a revelation to realize what a tremendous improvement in the corrosion-resistance of the finish is obtained from a double-layer nickel coating. The nickel plate on these samples was interrupted at the half-way mark; the nickel was buffed and then the nickel plating continued. The astonishing improvement due to this double-layer plating method was confirmed at every one of the thickness ranges covered and at all the locations. The improvement is of such great magnitude that these possibilities should receive serious consideration, even though the double layer is an expensive step and requires skill.'

Under conditions of industrial exposure a copper undercoat may initially have some advantage.

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Nickel Coatings in the Engineering Field

Papers presented at the 6th International Mechanical Engineering Congress, held in Paris in June 1956, included a series dealing with the production, properties and uses of coatings deposited by chemical and electrolytic processes. The scope of such papers is briefly indicated below:—

– CHAMBAUD: 'Heavy Nickel Electrodeposits. A Remedy for Certain Forms of Fretting Corrosion.'
Paper A 2/4; 5 pp. + figures.

This paper deals specifically with the prevention of fretting corrosion in closely fitting parts, by means of electrodeposited coatings: the major interest is in nickel coatings, for which some typical service data are presented.

H. C. CASTELL: 'The Mechanical Properties of Nickel and Nickel-Alloy Deposits.'
Paper C 2/3; 11 pp. + figures.

The author reviews the effects of variation in hardness, internal stress, tensile strength and ductility, on the behaviour of various types of nickel electrodeposits. The effect of deposited nickel on the fatigue strength of coated components is discussed, and a further section of the paper deals with the modification of the mechanical properties of coatings by annealing. It is also shown that nickel and nickel-alloy deposits may be deposited from solutions and under conditions varied to give coatings suited for specific applications. Typical mechanical properties are reported for pure nickel deposits (in the dull and bright conditions), cobalt-nickel bright platings, tin-nickel deposits, and nickel-phosphorus deposits made by the electroless process.

– JOY: 'Electrodeposition of Very Thick Deposits.'
Paper C 2/8; 6 pp.

The paper deals with nickel plating of stereotypes. The advantages of the Watts bath for this purpose are urged, and the conditions of deposition are discussed.

J. M. ODEKERKEN: 'Pitting or Porosity of Electrolytic Deposits: their Remedy in Specific Cases.'
Paper C 2/11; 9 pp.

Causes of pores and pitting are discussed, in relation

to (1) the influence of the condition of the basis metal and its chemical treatment prior to plating, (2) the presence, in the electrolyte, of suspended material or dissolved impurities, and (3) unsuitable solutions or other plating conditions.

– FIEDLER: 'The Progress of Chemical Nickel Plating in the U.S.A. and in Europe.'
Paper C 3/14; 9 pp.

A review paper, with special reference to the development of electroless plating on the basis of work by Brenner and Riddell and later commercial development under the auspices of General American Transportation Corporation.

A. PORTALUPI and E. MELGARA: 'Improvement of Resistance to Oxidation and Wear of Metal Surfaces by Electroless Nickel Plating.'
Paper 3/9; 11 pp. + figures.

Tests on the physical and corrosion-resisting properties of nickel deposits made by the electroless process are reported in demonstration of the value of such coatings for mechanical-engineering applications in which resistance to wear, corrosion and erosion is required. Some comparisons are made between electroplated and electroless deposits.

– VAN ROYEN: 'Effect of Heat-Treatment of Phosphorus-Nickel Alloys on Resistance to Corrosion.'
Paper C 3/13; 9 pp. + figures.

The mechanism of deposition by the electroless process and the structure of the deposits obtained are briefly described, and observations are made on changes which result from three different types of heat-treatment.

R. STUDLER: 'Main Characteristics of the Phosphorus-Nickel Alloy: Its Physical and Electrical Properties and Its Use in Various Industries.'
Paper 3/15; 6 pp.

This paper also reviews the nature and properties of electroless nickel-phosphorus coatings. The applications of such deposits are not yet fully developed, but in the U.S.A. these coatings are already being used on hardware, printing machinery and parts of food-processing equipment.

Tin-Nickel Alloy Deposits

R. T. GORE and F. A. LOWENHEIM: 'Is Tin-Nickel the New Plating Finish You Need?'
Iron Age, 1956, vol. 177, May 31, pp. 59–61.

The article is one of a series dealing with the various forms of alloy plating which are in current commercial use. The coating described is the 65–35 tin-nickel type developed by the Tin Research Institute (on which much detailed information has been presented before the Institute of Metal Finishing: see, for example, abstract in *Nickel Bulletin*, 1955, vol. 28, No. 12, p. 214).

The characteristic properties of tin-nickel coatings are reviewed (e.g., corrosion-resistance and resistance to tarnishing, hardness and wear-resistance, freedom from internal stress, low coefficient of friction). Conditions for electrodeposition of the alloy coating are briefly noted and some of its applications are illustrated.

NON-FERROUS ALLOYS

Diffusion of Other Elements in Nickel

See abstract on p. 157.

Structure in Titanium-Nickel Alloys

D. H. POLONIS and J. G. PARR: 'Substructures in Retained-Beta Phase of Ti-Ni Alloys.'
Jnl. of Metals, 1956, vol. 8, May, Pt. II; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 514–15. T.N. 307 E.

This note describes substructure in retained β phase in low-nitrogen nickel-titanium alloys quenched from 1000°C. by a blast of helium gas. It is suggested that the structures observed are due to polygonization resulting from unrelieved stresses set up during thermal transformation.

D. H. POLONIS and J. G. PARR: 'Phase Transformations in Titanium-Rich Alloys of Nickel and Titanium', *ibid.*, pp. 531–6.

Study of the formation and subsequent decomposition of metastable phases in titanium-nickel alloys containing up to 11 at. per cent. of nickel. The decomposition of a completely retained β phase and of a completely transformed β phase was followed in a 6 per cent. nickel alloy by means of X-ray diffraction examination, metallographic inspection and hardness determination. Suggestions are made to explain the mechanism of the reactions involved.

Yield and Bursting Data for Cylinders of Nickel-containing Materials

See abstract on p. 167.

Elevated-Temperature Properties of Nickel-containing Copper-base Alloys

C. UPTHEGROVE and H. L. BURGHOFF: 'Elevated-Temperature Properties of Coppers and Copper-base Alloys.'
Amer. Soc. Testing Materials Special Tech. Publn. 181, 1956; 244 pp.

This report is one of a series prepared under the auspices of the A.S.T.M./A.S.M.E. Joint Committee on Effect of Temperature on Properties of Metals. Earlier items in the series have covered, respectively, 'The Strength of Wrought Steels at Elevated Temperatures' (1950) and 'The Elevated-Temperature Properties of Stainless Steels' (1952).

The information presented, in tabular and graphical form, is based on data accumulated by the Committee over a long period, together with material supplied by fifteen organizations in the U.S.A. and in England.

The main classification used is as under:—

Copper
Brasses
Aluminium Bronzes
Cupro-Nickel Alloys and Nickel Bronzes
Silicon Bronzes
Tin Bronzes.

These groups are further sub-divided, mainly on the basis of composition and, for coppers, according to processing method. In many cases the schedules also show the A.S.T.M. specifications to which the various materials conform, and the physical condition in which the tests were made is indicated (cast, wrought, annealed, cold-worked, aged).

The data presented cover mechanical properties for approximately 50 alloys and types of copper. Temperatures are usually in the range 300°-900°F. (150°-480°C.), but in a few cases test results at 1500°F. (815°C.) are recorded. Creep data are for the 300°-500°F. (150°-260°C.) range.

Nickel-containing copper-base materials for which information will be found in this volume are listed below:—

Nickel-Phosphorus Copper
Tellurium-Nickel-Phosphorus Copper
Nickel-Brass (Nickel Silver)
Aluminium-Iron-Nickel Bronze
Aluminium-Nickel Bronze
Aluminium-Nickel-Silicon Bronze
Cupro-Nickel (10, 20 and 30, per cent. Nickel)
Nickel-Aluminium-Cadmium Bronze
Nickel-Tin-Lead-Zinc Bronze
Nickel-Iron-Tin Bronze.

Scaling Characteristics of Nickel-Manganese Alloys

See abstract on p. 170.

Thermal Conductivity of Metallic Materials at Elevated Temperatures

See abstract on p. 156.

Effects of Irradiation on Nickel-containing Materials

See abstract on p. 156.

Reflectivity of Nickel and Other Metals

See abstract on p. 157.

Influence of Compression on Magnetic Properties of Nickel and Nickel Alloys

See abstract on p. 157.

Resistance of Monel to Corrosion by Chloramine

See abstract on p. 174.

Nickel in Zinc-base Die Alloy

J. C. HOLZWARTH and A. L. BOEGEHOLD: 'Gmoodie: A Low-Cost Die Material.'
Metal Progress, 1956, vol. 69, May, pp. 49-52.

The alloy described (G.M.O.O. die alloy: 'Gmoodie') is an improved material developed primarily for dies used in drawing, forming, flanging and bending of sheet metal, where the volume of output required exceeds the life expectancy of material generally used for short-run work.

Three main considerations were involved in development: cost, castability and wear-resistance. Existing zinc-base tool alloys fulfil the first two requirements, and it was considered that the most promising method of increasing wear-resistance was the addition, to such alloys, of a dispersion of hard, but relatively insoluble, particles. These hard particles would be comparable to a network of carbides in ferrous alloys, which improves resistance to rubbing wear.

A major problem was the development of a satisfactory method of incorporating the relatively insoluble particles in the alloy. In order to be retained in suspension they must be wetted by the molten alloy, but if there were appreciable solubility casting properties would be affected. In the early experiments silicon (introduced as an aluminium-silicon alloy) was used as the hardener, and manganese was added to lessen the tendency of the silicon particles to float in the higher-density zinc-base melt. Although the alloy thus modified showed improved wear-resistance, the results were not entirely consistent and satisfactory, and a search was therefore made for a hardening agent which would be of higher density and show less tendency to segregate. The hardener finally selected was a combination of nickel and titanium, believed to be the intermetallic compound of Ni_3Ti, and the new alloy, Gmoodie, in which this hardener is incorporated, shows wear-resistance equal to that of the silicon-manganese-modified alloy, while having better castability and homogeneity. To obtain particles having the desired wearing characteristics, nickel and titanium are added to the zinc in the form of a ternary alloy of copper, nickel and titanium: optimum combination of wear properties, castability and cost has been obtained in an alloy containing about 4 per cent. aluminium, 3·25 per cent. copper, 0·80 per cent. nickel, 0·20 per cent. titanium, 0·15 per cent magnesium, balance zinc.

Service experience of General Motors Overseas Operations, with the new die alloy, is recorded in this article, indicating its potential value to the sheet-metal-forming industry.

Nickel and Monel Equipment in Fluorine Production

See abstract on p. 175.

Nickel-containing Materials in Bourdon Pressure Gauges

See abstract on p. 156.

Nickel-Manganese Brazing Alloys

R. A. GUSTAFSON: 'Nickel-Manganese Brazing of Steel.'
Welding and Metal Fabrication, 1956, vol. 24, Aug., pp. 290-1.

The author urges the advantages of nickel-manganese

alloys for the brazing of high-strength joints in most types of steel (including the stainless steels), and in cobalt-base alloys. In most cases wire is used, but the nickel-manganese brazing media are obtainable also in powder form, for use as paste.

Notes are added on the technique of brazing with these alloys, and on the characteristics of the joints produced.

Silver Soldering of Monel to Brass

'Silver Soldering Joins Monel and Brass in Marine Fabrication.'

Welding Jnl., 1956, vol. 35, June, p. 590.

An annotated pictorial description of the fabrication of Monel petrol tanks for marine use. Brass fittings are silver-soldered to the tank, ensuring a strong bond with the 0·037-in. Monel sheet.

Production of Cobalt-58 by Irradiation of Nickel

See abstract on p. 161.

NICKEL-IRON ALLOYS

Solidification of a Metastable Phase in Iron-Nickel Alloys

R. E. CECH: 'Evidence for Solidification of a Metastable Phase in Fe-Ni Alloys.'

Jnl. of Metals, 1956, vol. 8, May, Pt. II; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 585–9. T.P. 4085 E.

It is shown that in small powder particles of an alloy containing nickel 29·5, iron 70·5 per cent. a body-centred-cubic phase nucleates from the liquid.

Evidence available to date on pure iron and on iron-nickel alloys containing 10, 20, 25 and 32, per cent. of nickel indicates that the same phenomenon probably occurs in such materials. The observations made provide experimental verification of an earlier prediction made by the author, based on solidification theory, that the solid phase which nucleates from a super-cooled liquid is not necessarily the most stable macroscopic phase.

Structure of Ultra-Thin Strip of Magnetic Alloys

M. F. LITTMANN: 'Cubic Texture in Ultrathin Tapes of 48 per cent. Ni-Fe Alloy.'

Jnl. of Metals, 1956, vol. 8, May, Pt. II; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 593–5; T.N. 331E.

The note deals with structure in improved types of high-permeability 48 per cent. nickel-iron alloy (Armco 48 Orthonik), as observed in tape of 1, $\frac{1}{2}$ and $\frac{1}{4}$ mil. thickness.

Thermal Conductivity of Metallic Materials at Elevated Temperatures

See abstract on p. 156.

Nickel-Aluminium-Iron-base Permanent-Magnet Materials of Controlled Structure

'Permanent Magnet Materials.'

Iron and Steel, 1956, vol. 29, June, p. 323.

Members of the Permanent Magnet Association are introducing three new materials, to be known as Alcomax II S.C., III S.C. and IV S.D. These materials are modified forms of P.M.A. Columax, which has the highest magnetic performance of any permanent-magnet alloy, but which is not suitable for economic bulk production. The structure of the three new materials is semi-columnar, and they are therefore more easily adapted to existing methods of large-scale manufacture. In performance they are intermediate between Alcomax and Columax.

The development of the crystal structure necessary to give improved performance is limited at present to certain shapes and sizes: plain solid cylinders having a diameter greater than $\frac{3}{4}$ in. and a length somewhat less than the diameter are most suitable, and, in the early stages of production, manufacture will be limited to such magnets. These materials will be of particular interest where solid cylindrical magnets are already being used, since it will be possible to reap the benefits of the new alloys without change of design or re-tooling.

In this note the structure of Alcomax III and Alcomax III S.C. are illustrated, and a graphical comparison is made between the properties of these two materials.

Influence of Compression on Magnetic Properties of Nickel and Nickel Alloys

See abstract on p. 157.

Magnetic Nickel-Iron Alloy: Specification

SOC. AUTOMOTIVE ENGINEERS: 'Magnetic Alloy Sheet and Strip.'

A.M.S. Specification 7701, issued July 1, 1956.

This specification relates primarily to parts used in magnetic circuits requiring high magnetic permeability at low flux densities after annealing at high temperatures in hydrogen. It is required that the alloy shall contain approximately 80 per cent. nickel, with iron and other alloying elements (usually copper and chromium) in such proportions as will meet the technical requirements for the finished alloy.

It is laid down that, after annealing by heating to 2050°F. (±25°) in a dry hydrogen atmosphere (−60°F. max. dew point), holding at that temperature for four hours and cooling to 1100°F. at a rate not faster than 100°F. per hour in a non-oxidizing atmosphere, the material shall show the following properties:—

(1) Maximum Permeability, min.	70,000	A.S.T.M. A341–49
(2) Permeability at 100 gausses, min.	15,000	
(3) Induction at 100 oersteds, gausses, min.	6,500	

Hardness is specified as not higher than Rockwell B75 or equivalent.

A related specification, *A.M.S.* 7702, also issued July 1, 1956, covers the properties of the material in the half-hard condition, showing hardness not lower than Rockwell B90 or equivalent. Magnetic property requirements are identical with those laid down for the annealed material.

Demagnetization of Magnets in Contact with Ferromagnetic Bodies

M. McCAIG: 'Demagnetization of Magnets due to Contact with Ferromagnetic Bodies.'

Jnl. Scientific Instruments, 1956, vol. 23, Aug., pp. 311–12.

Although it is well known that in instruments of which permanent magnets form an integral part contact with ferromagnetic bodies, e.g., tools used in assembly or adjustment, may impair the accurate functioning of the magnet, relatively few data are available on the extent of the damage which may thus be done to a magnet, and the circumstances in which it may occur.

This paper records tests made to elucidate the conditions in which permanent magnets are partially demagnetized by repeated contact with ferromagnetic bodies. The magnets tested were of the nickel-aluminium-iron-base types (Alcomax and Alnico alloys), and the ferromagnetic material employed was mild steel. It is shown that if a bar magnet is placed a few times on a block of mild steel and removed by a sliding motion parallel to its length, loss of magnetization of the order of 40 per cent. may occur. More than 3 mm. thickness of protective material is needed to ensure that the losses are kept below 1 per cent.

Nickel-Iron-Molybdenum Powder Cores

C. D. OWENS: 'Stability Characteristics of Molybdenum Permalloy Powder Cores.'

Electrical Engineering, 1956, vol. 75, Mar., pp. 252–6.

Cores made from compressed powder of molybdenum Permalloy (nickel 82, iron 16, molybdenum 2, per cent. alloy) have been in use for some 20 years, in loading coils, filter coils and transformer coils, at voice and carrier frequencies in telephone plant. Recently the use of such cores has been extended to many industrial and military circuits, in particular for applications in which very small size and high precision and stability are essential. Stability of permeability, and core losses as influenced by time, temperature and flux levels, are important design factors, and, as an aid to engineers using such cores, the author of this paper discusses inherent stability characteristics, and the features of equipment design which may affect them. The reports of behaviour and the recommendations made are based on practical experience in telephones. Methods used for production of the powder and fabrication of the cores are briefly noted and properties and behaviour are considered in sections relating, respectively, to air-gap structure in powder cores, effects of moisture on permeability, effect of temperature changes, influence of waxes in the insulation media, the effects of external pressure applied to the cores, the inter-relation of flux density and permeability, core losses, and dielectric properties.

Stress-Corrosion Cracking in Nickel-Iron Alloy

M. H. DAVIES: 'Cracking of D.T.D. 247 High-Thermal-Expansion Alloy.'

Iron and Steel, 1956, vol. 29, June, pp. 321–2.

Stress-corrosion cracking in tubing of a 36 per cent. nickel-iron alloy used in a fire-detector switch was found to be attributable to surface deformation of the material during machining. Exposure to marine atmospheric conditions was a possibly accelerating factor.

Use of tubes annealed after drawing, or full annealing of machined tubes subsequent to machining, is recommended to ensure immunity from cracking, and attention is drawn to the importance of avoiding such operations as stamping of number or trade identification marks on thin sections.

Corrosion of Nickel-Iron Welds in Caustic Solutions

See abstract on p. 174.

Metallographic Examination of Nickel Ferrites

P. LEVESQUE and L. GERLACH: 'The Metallography of Ferrites.'

Jnl. Amer. Ceramic Soc., 1956, vol. 39, Mar. 1, pp. 119–20.

The authors make recommendations for preparation of ferrite specimens and show, with comments, photomicrographs illustrating the structures typical of nickel and zinc-nickel ferrites. Although the method of grinding and polishing a ferrite specimen may vary slightly with the nature of the material, the following procedure is recommended as a general guide:—rough grind on a silicon-carbide cloth, grit 400, and afterwards on silicon-carbide cloth, grit 600, and on Microcut paper. All the grinding operations can be done on a horizontal wheel at 550 r.p.m., using a 25 per cent. alcohol-water solution. For very friable samples an intermediate step between the fine grinding and the usual polishing may be necessary: this consists in polishing on a silk wheel lightly charged with 1200-grit lapping compound.

Surfaces obtained by wet-grinding methods can in most cases be easily polished with a 1 μ Diamet-Hyprez paste on kitten-ear broadcloth, or with aluminium oxide (1 μ) or chromic oxide (1 μ) on a heavily loaded silk wheel at 550 r.p.m. For the final polishing 0·5 - μchromic oxide, used on a silk wheel at 160 r.p.m., is suitable.

The following etchants may be used:—

For manganese ferrites: 50 per cent. aqueous hydrochloric acid; 4–15 min.; 85°–90°C.

For nickel and zinc ferrites: 50 per cent. conc. sulphuric acid, 50 per cent. satd. oxalic acid; 1 hour; 110°C.

Nickel-containing Materials in Bourdon Pressure Gauges

See abstract on p. 156.

CONSTRUCTIONAL STEELS

Formation of Martensite and Bainite in Low-Alloy Nickel-containing Steels

W. STEVEN and A. G. HAYNES: 'The Temperature of Formation of Martensite and Bainite in Low-Alloy Steels. Some Effects of Chemical Composition.'
Jnl. Iron and Steel Inst., 1956, vol. 183, Aug., pp. 349–59.

Consideration is given to possible sources of error in the method proposed by GRENINGER and TROIANO for determination of martensite-formation ranges (*Trans. Amer. Soc. Metals*, 1940, vol. 28, pp. 537–63). It is shown that although this method is satisfactory for the determination of the M_s temperatures of a wide variety of steels, its suitability for study of rates of formation of martensite below the M_s temperature is restricted to steels of relatively high hardenability, because of the nucleating effect of martensite on bainite formation.

In the experimental work reported, the martensite- and bainite-transformation characteristics of a wide variety of commercial and laboratory-made steels were determined, and from a consideration of the resulting data empirical formulae were derived relating composition and certain transformation temperatures.

From the following equations it is possible to calculate, within $\pm 20-25$°C. with a 90 per cent. certainty, M_s and B_s temperatures of steels within the following limits of chemical composition:—carbon 0·1–0·55, chromium trace–3·5, manganese 0·2–1·7, molybdenum trace–1·0, nickel trace–5, per cent.

Equations

$$M_s\ (°C.) = 561 - 474C - 33Mn - 17Ni - 17Cr - 21Mo$$

$$B_s\ (°C.) = 830 - 270C - 90Mn - 37Ni - 70Cr - 83Mo$$

Within the same range of chemical composition the following simple relationships exist between the B_{50} and E_f temperatures and the B_s temperature:

$$B_{50}\ (°C.) = B_s - 60$$

$$B_f\ (°C.) = B_s - 120$$

The martensite-formation ranges of eleven steels of relatively high hardenability and having carbon contents between 0·32 and 0·44 per cent. conformed to the following relationships:—

$$M_{10}\ (°C.) = M_s - 10$$

$$M_{50}\ (°C.) = M_s - 47$$

$$M_{90}\ (°C.) = M_s - 103$$

$$M_f\ (°C.) = M_s - 215$$

Over the range $M_s - M_{70}$ the amount of martensite formed increased linearly with fall of temperature, but below M_{70} the rate of formation decreased progressively as the temperature was lowered.

Isothermal Characteristics of Carburized Nickel-Molybdenum Steel

G. MAYER and R. H. HICKLEY: 'The Isothermal Transformation Characteristics of Carburized 2 per cent. Nickel-Molybdenum Steel.'
Mond Nickel Co., Ltd. Publn. 1026,* 1956.
Reprint from *Metallurgia*, 1955, vol. 52, Nov., pp. 236–9.

For abstract see *Nickel Bulletin*, 1956, No. 1, p. 12.

Effect of Lead on the Fatigue Properties of Nickel-Alloy Steels

W. E. BARDGETT: 'Lead Additions: Effect on the Fatigue Properties of En 24 and En 36 Steels.'
Iron and Steel, 1956, vol. 29, Aug., pp. 392–5.

The advantages of making a small addition of lead to steels, in order to improve machinability and to give increased tool life, have been well established in practice, and it has been demonstrated that this improvement can be obtained without any material loss in strength, ductility, or toughness, or any lowering of general service performance. With regard to fatigue-resistance only limited data have been available, but they indicate that the effect of lead on fatigue strength of specimens free from stress concentrations is dependent on the tensile strength of the steel: it is probably without effect at levels up to about 55 t.s.i., but detrimental in steels of higher tensile strength. Notch-sensitivity in fatigue is apparently not affected by the presence of small amounts of lead.

In view of the increasing use of leaded steels in high-duty parts, and the fact that such components are frequently subjected to fluctuating loads in the presence of stress raisers, additional research has been carried out on this aspect, by United Steel Companies, Limited. One cast of steel† was selected for test at three different tensile levels (55, 70 and 110 tons per sq. in.), and two casts‡ from a second composition were used, one of which was treated to the lowest level of tensile strength used for steel of the first cast (55 tons) and the other to the middle value (70 tons). Leaded and non-leaded samples were obtained from each cast.

The record of the tests on these steels established the following facts:—

(1) *Tensile Properties*

The results on both types of steel confirm previous conclusions that although the additions of lead to an alloy steel may tend to reduce its tensile and ductility values at all levels, the effect is so slight as to be of little practical significance.

(2) *Rotary-Bending Fatigue Properties*

Only at high levels of tensile strength, and where no stress raiser is present, does the presence of lead cause any substantial lowering of the rotary-bending-fatigue strength of the steels tested, and it is pointed

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† 1¼ per cent. nickel-chromium-molybdenum direct-hardening steel (En 24).
‡ 3 per cent. nickel-chromium case-hardening steel (B.S. En 36.)

out that such conditions very rarely arise in engineering practice.

Yield and Bursting Data for Cylinders of Nickel-containing Materials

J. H. FAUPEL: 'Yield and Bursting Characteristics of Heavy-Wall Cylinders.'

Trans. Amer. Mechanical Engineers, 1956, vol. 78, July, pp. 1031–61; disc., pp. 1062–4.

Over a prolonged period about 100 heavy-wall cylinders have been tested to bursting at the Engineering Research Laboratory of E.I. du Pont de Nemours & Company, Inc. The cylinders tested were of plain carbon steels, various low-alloy steels, stainless steels of the chromium and chromium-nickel types, nickel-lined steels, and aluminium bronze. The materials covered the following range of mechanical properties:—ultimate strength 66,000–188,000 p.s.i. (29·5–84 tons per sq. in.); transverse ductility (elongation in 1 in.) 4–66 per cent.; longitudinal ductility (elongation in 2 in.) 12–83 per cent.

The work reported deals primarily with the characteristics of initially stress-free heavy-wall cylinders in the temperature range 75°–660°F. (23·8°–350°C.), and from the data obtained formulae have been developed which predict elastic-breakdown pressure and bursting pressure for static loading.

Thermal Conductivity of Steels at Elevated Temperatures

See abstract on p. 156.

Factors Affecting Notch Sensitivity in Low-Alloy Nickel-Chromium-Molybdenum Steel

G. SACHS, V. WEISS and E. P. KLIER: 'Effects of a Number of Heat-Treating and Testing Variables on the Notch Strength of 4340 Steel.'

Amer. Soc. Testing Materials, Preprint 71, June 1956; 11 pp.

The tests reported were made on a low-alloy steel, in three conditions, resulting, respectively, from heat-treatments designed to produce various structures. The composition of the steel was as follows:—carbon 0·38–0·39, silicon 0·29, manganese 0·76, sulphur 0·015, phosphorus 0·015, nickel 1·84, chromium 0·72, molybdenum 0·23, per cent. Tests on sharply notched bars, performed at sufficiently low temperature (−320°F.; −196°C.) show that if tempered between 500° and 700°F. (260° and 370°C.) this steel tends to be highly notch-sensitive on static loading. The tests also indicate that a two-step quenching treatment is to be preferred in treating the steel to high strength levels.

British and U.S. Steel Specifications

W. B. KEMMISH: 'A Comparison Between British En and American S.A.E. Steels.'

Machinery (Lond.) 1956, vol. 89, July 20, pp. 167–9.

In view of the tendency towards closer integration between the engineering industries of Great Britain and the U.S.A., a knowledge of the specifications operative in the two countries is essential to designers and to suppliers of constructional materials. This article outlines the basic differences in methods of specifying in the U.K. and the U.S.A. and presents a tabular summary of steel specifications of the B.S. En and S.A.E. series. The types covered include free-machining and carbon steels, manganese steels, low-carbon steels for cold-forming applications, manganese-molybdenum, nickel-chromium, nickel-molybdenum, nickel - chromium - molybdenum, chromium, and chromium-molybdenum types.

Attention is directed also to the boron-containing steels and the H series (specified according to hardenability characteristics), both of which groups are covered by specifications drawn up by the American Iron and Steel Institute.

Determination of Nickel in Ferrous Materials

AMER. SOC. TESTING MATERIALS: 'Proposed Revised Tentative Methods for Chemical Analysis of Steel, Cast Iron, Open-Hearth Iron and Wrought Iron.'

A.S.T.M. Preprint 57a, June 1956, pp. 1–17.

The schedule contains the latest revised procedure for the following determinations:—

Manganese by the Periodate (Photometric) Method.
Nickel by the Dimethylglyoxime (Photometric) Method.
Magnesium by the Oxyquinolate (Mercury Cathode) Method.
Niobium and Tantalum by the Hydrolysis (Photometric) Method.

The process for the estimation of nickel is applicable to the analysis of ferrous alloys containing not more than 4 per cent. of that element. Full details of procedure are given, including provision for overcoming the influence of interfering elements (copper, manganese and cobalt).

Properties of Nickel-Molybdenum-Vanadium Steel Welding Electrodes

E. H. FRANKS and W. H. WOODING: 'Some Dynamic Mechanical Properties of Heat-Treated Low-Alloy Weld Deposits.'

Welding Jnl., 1956, vol. 35, June, pp. 291S–7S.

Reprint issued by *International Nickel Co., Inc.*

Among recently developed electrodes found to be suitable for the arc welding of low-alloy steels, the nickel-molybdenum-vanadium steel type (A.W.S. E10015-16) has met with considerable success. These electrodes are of a heavy mineral-covered type, the coating of which is relatively free of hydrogen and hydrogen-producing compounds, e.g., water. The absence of water also permits transfer across the arc of such elements as manganese, silicon and vanadium, without severe loss of oxidation. Deposits made from these electrodes show a tensile strength of more than 100,000 p.s.i. (44·6 tons per sq. in.), and the weldments have given excellent performance in a variety of tests, including impact.

The electrodes are finding wide acceptance for welding of low-alloy steel structures, particularly where a high degree of restraint is encountered,

but at present only limited use is being made of them in the construction and repair of machinery, due, it is believed, to the fact that relatively little information is available concerning the performance of the weldments under cyclic loading, particularly after heat-treatment.

This paper reports tests made to amplify such information. It records the mechanical properties, including impact and fatigue strength, for nickel-molybdenum-vanadium steel weld deposits, in the as-welded, stress-relieved, quenched-and-tempered, and annealed conditions. The results show that the deposits are of good quality, possessing, in both the as-welded and heat-treated conditions, excellent ductility, and showing high endurance limits under cyclic and reversed stress. It is therefore concluded that the A.W.S. E10015-16 types of electrode offer considerable promise for use in engineering applications, particularly where fatigue properties are of primary importance.

Effects of Nuclear Irradiation on Steels

See abstract on p. 177.

Cleaning of Radio-Contaminated Metals

See abstract on p. 156.

HEAT- AND CORROSION-RESISTING MATERIALS

Properties of Heat-Resisting Materials at Moderately Elevated Temperatures

J. G. SESSLER and W. F. BROWN: 'Notch and Smooth Bar Stress-Rupture Characteristics of Several Heat-Resistant Alloys in the Temperature Range between 600° and 1000°F.'

Amer. Soc. Testing Materials, Preprint 76, June 1956; 15 pp.

Applications of heat-resisting alloys in aircraft gas turbines have until now been in service involving temperatures well over 1000°F. (540°C.), and service lives of only a few hundred hours. Such conditions completely exclude the use of many ferritic and austenitic heat-resisting alloys which are in use in the steam-power and chemical-processing industries. Recently, applications for heat-resisting materials have widened to fields in which lower metal temperatures are involved, but longer life is called for. This temperature range extends from the lowest region in which creep must be considered to about 1000°F. (540°C.): it thus overlaps the range encountered in the steam-turbine industry. Environmental conditions in these newer applications are, however, quite different from those in the steam-engineering field, and, due to weight considerations, stresses are considerably higher. Further, the possibility of exceeding the design temperatures during operation must be considered. At these moderately elevated temperatures the ferritic heat-resisting steels are in competition with expensive 'super alloys', and of particular interest are low-alloy steels and the martensitic stainless types modified by additions of vanadium, tungsten or boron in association with increased carbon up to 0·30 per cent.

A problem facing the design engineer is the selection, from this range of available materials, of the one most suitable for use in any specific application. The tests reported in this paper were designed to provide data which can be of service in this connexion. The materials examined are shown in the Table on page 169.

Smooth and sharply notched bar stress-rupture tests were carried out on these materials in the temperature range 600°-1000°F. (315°-540°C.) for rupture times up to 1,000 hours. The results, which are graphically reported for the individual materials, led to the following conclusions:—

Structural steels of the low-alloy nickel-chromium-molybdenum type (S.A.E. 4340) may be heat-treated to high levels of strength, and such materials will possess very high rupture strength at temperatures below 600°F. (315°C.), but at higher temperatures the rupture strength falls rapidly, due to lack of stability.

Inconel X exhibited the highest stress-rupture strength and greatest stability of strength over the temperature range used.

Alloy A 286 showed similar stability, but considerably lower strength in this range of temperature.

Below about 800°F. (425°C.) the 100-hour rupture strength of the modified ferritic steels and of the precipitation-hardening steel 17-4 PH is well above 100,000 p.s.i. (44·5 tons per sq. in.), and these steels are definitely competitive, in this temperature range, with materials of the A-286 type.

For both the 'super alloys' and the modified ferritic steels the yield strength is below the 1,000-hour rupture strength at temperatures below about 800°F. (425°C.). Both Inconel X and A-286 show notch-rupture strength ratios less than 1·2 at temperatures between 600°-800°F. (315°-425°C.). The precipitation-hardening steel 17-4 PH, when tempered at 1000°F. (540°C.), shows very severe notch-sensitivity in the range 600°-1000°F. (315°-540°C.). The remainder of the materials examined show indications of developing notch-sensitivity at 800°F. (425°C.) and above.

The rupture strength of normalized and tempered ferritic steels at moderately elevated temperatures can be considerably improved by increasing their hardness, but a possible limitation in this connexion is development of notch-rupture sensitivity associated with increase in hardness.

Tensile Fatigue in Gas-Turbine Alloy

C. A. HOFFMAN: 'Strengths and Failure Characteristics of A.M.S. 5534A (S-816) Alloy in Direct Tensile Fatigue at Elevated Temperatures.'

Amer. Soc. Testing Materials, Preprint 68, June 1956; 18 pp.

Under steady-state operating conditions the stresses on a turbine blade are a combination of centrifugal

Table I

Composition of Alloys Investigated

Alloy	C %	Cr %	Ni %	Mo %	Mn %	Si %	Fe %	Others %
SAE 4340	0·39	0·72	1·82	0·28	0·71	0·29	Bal.	
SAE 4340	0·40	0·82	1·82	0·24	0·70	0·29	Bal.	
17-22A (S)[a]	0·30	1·25	0·34	0·51	0·62	0·68	Bal.	0·25 V
AMS 5616	0·12	12·88	1·98	0·50	0·35	0·31	Bal.	2·86 W
17-4PHa	0·05	17·86	4·43	—	0·64	0·33	Bal.	3·91 Cu 0·36 Nb + Ta
AISI 410[b]	0·15 max.	12	—	—	1·00	1·00	Bal.	
Inconel X[b]	0·08	15	72	—	0·70	0·50	7	2·5 Ti 1·0 Nb 0·7 Al
A-286[b]	0·08 max.	15	25	1·25	1·50	1·00 max.	Bal.	2·0 Ti 0·25 V 0·30 Al

a These alloys were also subjected to special heat-treatments, of which particulars are given in the paper.

b Nominal composition.

stress and superimposed vibratory stress, and, due to the presence of the vibratory stress, the lives of turbine blades may be considerably shorter than would be predicted from stress-rupture data alone.

In the analysis of service behaviour, the appearance of the fracture surface is frequently used to indicate the cause of failure, since vibratory stress is expected to cause the fracture to exhibit an appearance characteristic of fatigue. The appearance of a blade failure, *per se*, is not, however, conclusive evidence of the effect of vibratory stress on blade life.

This paper reports the results of a comprehensive investigation of high-temperature tensile fatigue, made in one of the laboratories of the National Advisory Committee for Aeronautics. The alloy used was S-816*, a material widely employed in the U.S.A. for wrought gas-turbine blades. Observations were made of failure in relation to mean stress, temperature, vibratory stress, and time-to-fracture, and metallographic examination was carried out to elucidate the relation of the fracture path to the crystallographic features of the alloy at elevated temperature. The effects of cyclic vibratory stress on reduction in area and hardness at failure were also investigated.

The tests were made at three temperatures, 1200°, 1500° and 1600°F. (648°, 815° and 870°C.). Stress-rupture data were first obtained, and from these values a selection was made of mean stresses which would yield failure times, at each temperature, of approximately 10, 100 and 1,000 hours with zero cyclic stress. Cyclic tensile stresses up to a maximum of about 98 per cent. of the mean stresses were superimposed on these mean stresses, usually in increments of ±2,500 p.s.i. The cyclic stresses were applied at 2,000 c.p.m. The criterion of failure was complete fracture of the specimen.

An illustrated description is given of the fatigue machine on which the tests were made, and the methods of examination and evaluation of the specimens are discussed.

The results led to the following conclusions:—

At all conditions of mean stress and temperature investigated, increasing cyclic stress reduced time-to-failure (life). Under some conditions, however, the reductions, if any, were slight at the lower cyclic-stress magnitudes.

Superimposed cyclic stresses of a given magnitude (low to intermediate) generally resulted in relatively greater reductions in life at the lower mean stresses (longer lives) than at the higher mean stresses (shorter lives).

Cyclic stresses of given magnitudes caused greater reductions in life at 1200°F. (648°C.) than at 1500° and 1600°F. (815° and 870°C.).

With increased cyclic vibratory stress about a mean stress, the appearance of the failure was indicated as undergoing a transition from that of stress-rupture to a combination of stress-rupture and fatigue. Further increases in vibratory-stress level resulted in the occurrence of fatigue failure. The appearance of fatigue-type failures was generally

*Carbon 0·40, silicon 0·063, manganese 1·45, sulphur 0·008, phosphorus 0·005, nickel 19·80, chromium 19·93, tungsten 3·81, cobalt 42·02, niobium 4·07, iron 3·35, tantalum 0·27, copper 0·09, molybdenum 3·09, per cent.

accompanied by reductions in life, because of cyclic vibratory stress.

Under some conditions, failures apparently of the stress-rupture types occurred even though the life of the specimen had been lowered by cyclic stress.

Stress-rupture fracture occurred by transgranular cleavage and shear at 1200°F. (648°C.), and by intergranular failure and transgranular shear at 1500° and 1600°F. (815° and 870°C.). At all three temperatures, fatigue fracture was transgranular, and did not appear to follow crystallographic planes.

In all the conditions investigated, percentage reduction in area at failure (fracture ductility) decreased with increasing vibratory stress.

High-Temperature Thermal and Mechanical Properties of Inconel

W. J. O'SULLIVAN: 'Some Thermal and Mechanical Properties of Inconel at High Temperatures for Use in Aerodynamic Heating Research.'

Proc. Amer. Soc. Testing Materials, 1955, vol. 55, pp. 757–63.

Research on the design of supersonic aircraft and guided missiles has brought into prominence the need for closer knowledge of the phenomenon of aerodynamic heating, and its effects on the materials of construction used in aircraft.

This paper, covering work carried out by the National Advisory Committee for Aeronautics, opens with notes on the occurrence and mechanism of aerodynamic heating, as an introduction to study of properties which are significant in determining the effect of such heating on the service behaviour of constructional materials used at high temperatures.

The experimental work reported was done on Inconel, as being a typical material of construction in the field under consideration. The alloy was examined at three levels of carbon content: 0·02, 0·07 and 0·11 per cent. It was tested in the annealed condition, selected in order that the specimens should be in a relatively stable state with regard to intermetallic compounds and strain-energy content. Determinations were made of the following properties, within the temperature ranges shown:—

	°F.	°C.
Specific Heat	0-1600	0-870
Thermal Conductivity	200-1300	93-705
Thermal Expansion ..	32-1800	0-982
Tensile Strength and 0·2 per cent. Offset Yield Strength Electrical Resistance (0·02 and 0·11% C only) 0-2012–18 to + 1100	32-1800	0-982
Emissivity (0·02 and 0·07 % C only) ..	300-1400	150-760

Thermal Conductivity of Metallic Materials at Elevated Temperatures

See abstract on p. 156.

Yield and Bursting Data for Cylinders of Nickel-containing Materials

See abstract on p. 167.

Nickel-Chromium Borides

B. POST, E. PIPITZ and W. H. HERZ: 'A New Ternary Boride: Cr_2NiB_4.'

Powder Metallurgy Bull., 1956, vol. 7, Apr., pp. 149–52.

In the course of a systematic investigation of the chromium-nickel-boron system, a study was made of the structure of several ternary borides. This paper is devoted mainly to the characteristics of Cr_2NiB_4 (CrB_2 71·5, Ni 28·5 per cent.).

Scaling Characteristics of Nickel-Manganese Alloys

E. B. EVANS, C. A. PHALNIKAR and W. M. BALDWIN: 'High-Temperature Scaling of Nickel-Manganese Alloys.'

Jnl. Electrochemical Soc., 1956, vol. 103, July, pp. 367–75.

The report of experimental work on the scaling of nickel-manganese alloys is prefaced by summary discussion of data available on the scaling behaviour of nickel and of manganese.

Earlier investigations on nickel-manganese alloys have been confined to nickel-rich types (up to 10 per cent by weight of manganese): the results had indicated that such alloys oxidize according to the Pilling and Bedworth parabolic law. The scaling constant was observed to increase with rise in manganese up to the 10 per cent. limit studied.

The present authors covered a wider range of composition, using alloys containing 3·7, 9·1, 20·4, 24·1, 34·8 and 46·6 wt. per cent. of manganese. These alloys were one-phase (alpha), with the exception of the 46·6 per cent. manganese alloy, which showed a two-phase (alpha+theta) structure. The specimens were scaled in air for various times, at temperatures in the range 600°–1100°C.

The paper contains detailed and well illustrated data on the kinetics of scaling and on the pattern of the scales and subscales found on the respective alloys. The following conclusions were drawn from the observations made:—

The alloys all scaled according to the Pilling and Bedworth parabolic law. At a given temperature the scaling rate of the alloys increased with increasing additions of manganese, a characteristic which would appear to preclude their use for oxidation-resistant components.

The composition of both the external scale and the subscale was dependent on alloy composition and temperature. Above a critical concentration of manganese the external scale consisted exclusively of manganese oxides and MnO subscale: below this critical composition complex external scales of the oxides of both nickel and manganese were

formed, together with a subscale of NiO or a solid solution of monoxides. The critical concentration of manganese was as low as 15 per cent. at 600°C. and as high as 60 per cent. at 1000°C.

Increase in scaling rate associated with rise in manganese is due to (*a*) faster mobility of the manganese ion, or (*b*) an increase in lattice defects in the monoxide, introduced by manganese. The authors were unable to obtain sufficient evidence to distinguish between these two mechanisms.

Spinel formation observed in most of the complex scales had no apparent beneficial effect on scaling resistance.

The paper is supported by an extensive *bibliography*.

Influence of Carbon and Nitrogen on the Properties of Vacuum-Melted Stainless Steel

F. C. MONKMAN and N. J. GRANT: 'Low Carbon, Low Nitrogen Improve Stainless Properties.'

Iron Age, 1956, vol. 177, May 31, pp. 67–70.

The article is based on tests made at the Massachusetts Institute of Technology on vacuum-melted austenitic steels (chromium 15·6–19·4, nickel 10·4–8·0, per cent.), in which the carbon+nitrogen content was varied over the range 0·006–0·038 per cent. It is shown that the high-temperature strength and ductility of the alloys of lowest carbon+nickel content are markedly superior to those in which these elements are at higher levels. The finding with reference to high-temperature strength is in agreement with previous work in which carbon and nitrogen were found to be detrimental to the high-temperature strength of 18–8 stainless steels.

A table and graphs compare the properties of five vacuum-melted alloys and an alloy melted in air. The data show that values of reduction in area and elongation for the vacuum-melted alloys were, within the limit of experimental error, independent of rupture life (or stress). Reduction in area for rupture lives of 10 and 500 hours, plotted as a function of carbon and nitrogen content, shows that the ductility of the vacuum-melted alloys is about twice that of comparable material melted in air. It is urged that the absence of embrittlement in these alloys, with increasing time of rupture or decrease in rate of strain, is a feature of considerable practical significance.

Attention is also directed to the difference in sulphur and manganese contents of the vacuum-melted and the air-melted alloys: it is believed that these variations may be related to the improved high-temperature properties of the vacuum-produced materials.

Some notes are added on the structure of the alloys after solution treatment and on their M_s temperatures.

Chromium-Manganese-Nickel Stainless Steels

R. E. PARET: 'Fabrication of Low-Nickel, High-Manganese Stainless Steels.'

Metal Progress, 1956, vol. 69, May, pp. 54–7.

This is the third article in a series issued under the direction of the Committee of Stainless Steel Producers, American Iron and Steel Institute, New York. Earlier articles appeared in *Metal Progress*, December 1955 and February 1956: see *Nickel Bulletin*, 1956, vol. 29, Nos. 3 and 5, pp. 53 and 94.

The information presented indicates that steels of the A.I.S.I. 200 chromium-manganese-nickel types can be formed and welded with dies, equipment and techniques normally used for the higher-nickel stainless steels. For embossing or extremely precise deep drawing the greater strength of the high-manganese steels may necessitate some modification in tooling.

Experience in fabrication of typical articles is used as a basis for recommendations of technique suitable for specific operations on the high-manganese steels, indication being given of minor modifications which must be made to accommodate their working characteristics:

See also—

R. E. PARET: 'Experience with High-Manganese Stainless Steels', *ibid.*, June, pp. 68–71.

In this section information on composition and general properties of chromium-nickel-manganese stainless steels is summarized. Points to which attention is directed include the necessity for low nitrogen content, the resistance of the ternary steels to corrosion and to scaling, their elevated-temperature properties, and their work-hardening characteristics. (Reprints of these papers are issued by International Nickel Co., Inc.).

Martensite in 18-8 Chromium-Nickel Steels

P. G. BASTIEN and J. M. B. DEDIEU: 'Formation and Tempering of Martensite in 18–8 Steels.'

Jnl. Iron and Steel Inst., 1956, vol. 183, July, pp. 254–9.

The authors studied the possibility of effecting a considerable amount of $\gamma \rightarrow \alpha$ (martensitic) transformation in low-carbon 18–8 chromium-nickel steels.

It was found that simple cooling to very low temperatures (down to the boiling point of liquid hydrogen) produces transformation of only a small portion of the austenite, but that plastic straining slightly below or above normal temperature produces a considerable amount of the α-phase. Strain-hardening is not diminished by the possibility of transformation during working: in some cases it may actually be increased.

Dilatometric and X-ray examination demonstrated that the α-phase developed by plastic straining disappears if the steel is re-heated at a temperature above 550°C. The change is rapid between 550° and about 650°C., but the final stages of the reaction between 650° and 750°C. are relatively slow.

Re-heating at temperatures up to 500°C. has no effect on steels which have previously been transformed almost completely to α phase by plastic straining, but re-heating at higher temperatures causes progressive loss of hardness. The hardness of partially transformed steels is increased by re-heating at temperatures up to about 500°C.: the degree of increase depends on the composition of

the steel, the conditions of straining, and the re-heating temperature.

Sigma Formation in Stainless Steels

G. F. TISINAI, J. K. STANLEY and C. H. SAMANS: 'Sigma Nucleation Times in Stainless Steels.'

Jnl. of Metals, 1956, vol. 8, May, Pt. II; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 600–4. T.P. 4066E.

The paper is based on observations made on seven types of stainless steel (five austenitic types containing varying amounts of nickel and chromium, and two straight-chromium steels).

The data obtained, from X-ray diffraction and metallographic examination of highly-strained filings, and from metallographic inspection of annealed bulk samples, led to the following conclusions:—

The σ phase forms in the austenitic, as well as the ferritic, commercial stainless steels, in accordance with a C-type reaction curve suggested by earlier investigators. The curves for cold-worked material (filings) and for annealed bulk material were found to be reasonably similar, the main difference being that for annealed material the curve is displaced to longer times. The temperature at which σ forms most rapidly is dependent on composition, and maximum temperature of σ formation in filings also varied with composition. Pre-treatments at 1750° and 2250°F. (953° and 1230°C.) have little or no influence on the temperature of σ formation in filings, and noticeably affected the time to nucleate σ only in straight 18-8 and niobium-stabilized austenitic steels: pre-treatment at 2250°F. (1230°C.) retarded the time of nucleation. In stainless steels susceptible to σ formation this phase formed much more rapidly in severely cold-worked samples (filings) than in annealed bulk samples.

Precipitation and Intercrystalline Corrosion Phenomena in Titanium-Stabilized Chromium-Nickel Steels

K. BUNGARDT and G. LENNARTZ: 'Precipitation Phenomena in an Austenitic Chromium-Nickel Steel Stabilized with Titanium and its Relation to Intercrystalline Corrosion.'

Archiv f.d. Eisenhüttenwesen, 1956, vol. 27, Feb., pp. 127–33.

Although 18–8 type chromium-nickel steels can be stabilized by addition of carbide-forming elements (titanium, niobium or tantalum), to a degree ensuring satisfactory resistance to intercrystalline breakdown in service, it has been observed that in some cases steels of this type, if they contain the addition elements in more than the stoichiometric proportion, may, after quenching from the temperatures normally used (e.g., 1100°C.), show a slight tendency to intercrystalline corrosion when re-heated at 600°–700°C.

This phenomenon, which at first appeared to conflict with the theory of chromium impoverishment, has been considered to be associated with the increased solubility of special carbides at higher quenching temperatures, and it has also been noted that the duration of exposure in the 600°–700°C. range is a significant factor. For example, a titanium-stabilized steel quenched from 1050°–1100°C. proved to be resistant to intercrystalline breakdown after re-heating for only a short time in the 600°–700°C. range, whereas exposure to the same temperature for 100 hours resulted in intercrystalline corrosion. This effect could be prevented by treatment of the steel for 2 to 4 hours at 850°–900°C. prior to exposure in the 600°–700°C. range.

These observations led to the conclusion that the solubility of titanium carbide at 850°–900°C. is as low as that of $Cr_{23}C_6$ at 600°C. and that there must be a region of temperature in which, as a result of too low a rate of diffusion of the titanium, and the very considerably higher concentration of chromium, the dissolved carbon must precipitate mainly as $Cr_{23}C_6$.

In the light of the above findings the work described in the present paper was carried out, as a contribution to the study of the validity of the chromium-impoverishment theory. An investigation was made of the solubility of carbon in a titanium-stabilized chromium-nickel steel as a function of temperature, and this was correlated with the precipitation occurring in the same steel quenched from various temperatures and re-heated at temperatures in the range 500°–800°C.

The composition of the steel used was as follows:—carbon 0·067, silicon 0·43, manganese 0·98, chromium 17·52, nickel 10·44, molybdenum 0·38, nitrogen 0·013, titanium 0·47, per cent.

Specimens were heated, for the periods shown below, at 50° intervals within the given ranges, and were water-quenched:—

A.	15 minutes	at	1050°–1300°C.
B.	1 hour	at	900°–1300°C.
C.	2 hours	at	900°–1200°C.
D.	5 hours	at	900°–1000°C.

After quenching, the specimens of series A and B were re-heated as indicated below:—

100, 500 and 2,000 hours	at	500°C.
5, 20, 100, 500 and 2,000 hours	at	600°C.
5, 20, 100 and 500 hours	at	700°C.
2, 5, 20 and 100 hours	at	800°C.

Susceptibility to intergranular breakdown was evaluated by means of the standard copper-sulphate test.

Conclusions drawn from the extensive data reported are summarized below:—

At 500°C. there was no significant precipitation of TiC or $Cr_{23}C_6$ and specimens heated at that temperature showed no intergranular attack.

At 600°C. only a small amount of TiC was precipitated and precipitation was slow, but $Cr_{23}C_6$, the amount of which increased with duration of heating, was much more rapidly precipitated. In specimens which had been heated for 15 minutes intergranular breakdown was observed after 5 hours in the test solution, but in specimens which had been kept for 1 hour at that temperature structural breakdown

occurred only after 2,000 hours of exposure in the copper-sulphate solution.

At 700°C. titanium carbide and chromium carbide were simultaneously formed, and the reaction was more rapid than at 600°C. After 100 hours the chromium carbide again went into solution: at that stage sigma phase began to appear. Specimens in this condition showed no susceptibility to intergranular corrosion.

The phenomena observed at 800°C. were similar to those occurring at 700°C., but the reactions were more rapid. Specimens re-heated at this temperature were also immune from intergranular attack.

In commenting on these findings, the authors demonstrate that the relation between precipitation and intergranular breakdown gave unqualified support to the theory of chromium impoverishment as a cause of susceptibility to intercrystalline corrosion.

Corrosion and Erosion of Nickel by Molten Caustic Soda

J. N. GREGORY, N. HODGE, J. V. G. IREDALE: 'The Corrosion and Erosion of Nickel by Molten Caustic Soda and Sodium Uranate Suspensions under Dynamic Conditions.'
Atomic Energy Research Establishment, Harwell. *A.E.R.E.* C/M 273: *R.C.T.C.* P/54, 1956; 10 pp. + figures.

An earlier report (A.E.R.E. C/M 272: R.C.T.C. P/62) had covered studies on the behaviour of nickel in contact with molten caustic soda under static conditions. The present report deals with corrosion and erosion under dynamic conditions.

The tests were in two sections:—

(1) Corrosion rates of nickel specimens rotated at varying speeds in the molten caustic soda at various temperatures were compared with the static rates reported earlier. Some additional tests were made in the presence of uranate, to discover what proportion of the loss in weight undergone is due to erosion by sodium-uranate particles.

(2) Tests were devised to simulate fairly closely the conditions which would prevail in a homogeneous reactor based on caustic soda. This section of the experiments included consideration of problems associated with circulating the melt round a loop of nickel tubing of various diameters.

From the results recorded, the following conclusions are drawn:—

Corrosion and erosion would be serious limitations to the use of a caustic-soda slurry in nickel in a homogeneous reactor, and the temperature limit of the system under an inert atmosphere is about 550°C. At 600°C. the corrosion and erosion rate is equivalent to about $\frac{1}{8}$ in. per year. This estimate is based on average weight loss, but it is pointed out that the actual penetration of the nickel part at bends in pipes and at points of partial obstruction where the flow rate is specially high might well be some 300 per cent. above this value. At 500°C. and 300 r.p.m., however, the corrosion rate is equivalent to only 0·010 in. per year. Caustic soda in nickel might therefore offer a workable system between 320° and 550°C. or, if a eutectic of Li_7OH and NaOH is used, the temperature limits might be between 220° and 550°C.

The operation of thermosyphon loops showed that it is not practicable to use tubes of small internal diameter. For flowing caustic soda the limit would be about $\frac{3}{8}$ in. unless the system can be continuously evacuated to eliminate blockages due to gas locking, and the temperature limit for successful operation would be about 550°C. At temperatures above 550°C. the actual rate of corrosion is not so important as mass transfer. The quantity of mass transferred is approximately proportional to the greatest temperature difference in the system: it is negligible below 600°C., but above this temperature it increases rapidly.

The only known effective method of reducing the amount of mass transfer is to maintain a hydrogen-containing atmosphere in the proximity of the corrosion reaction, since the presence of hydrogen will tend to reverse the main corrosion reaction. (It is noted that experiments with thermosyphon loops are now in progress under such conditions.) Since, under a pure hydrogen atmosphere, sodium uranates in molten caustic soda are reduced to UO_2 (or $U(OH)_4$) such modification would require consideration, but from the corrosion standpoint there are marked advantages in the use of hydrogen, and it is believed that by such means the upper temperature limit of operation might be raised to about 700°C.

Resistance of Nickel to Corrosion by Fused Caustic

C. M. CRAIGHEAD, L. A. SMITH, E. C. PHILLIPS and R. I. JAFFEE: 'Continued Studies of Corrosion by Fused Caustic.'
U.S. Atomic Energy Commission AECD-3704, Dec. 18, 1952 (Declassified Oct. 4, 1955); 55 pp.

The report deals (*a*) with screening tests on a number of ceramic materials, to determine their resistance to sodium hydroxide at 1000°F. (538°C.), and (*b*) with the behaviour of L nickel (a special low-carbon grade).

The work covered a study of the behaviour of L nickel in sodium hydroxide at 1000°, 1250° and 1500°F. (538°, 675° and 815°C.). The results show that the rate of attack of this material by the molten hydroxide increases with rise in temperature, and that the attack is less severe when reducing atmospheres are used above the caustic than when a neutral atmosphere is present. In the tests at 1250° and 1500°F. (675° and 815°C.) solution and deposition of nickel under the influence of a temperature gradient was observed. (The phenomenon of mass transfer has been the subject of a number of recent papers—see, for example, abstracts in *Nickel Bulletin*, 1955, vol. 28, No. 4, p. 60, and 1956, vol. 29, No. 4, p. 71, also preceding abstract.)

Determination of the nickel content of sodium hydroxide which had been held in nickel containers

at various temperatures indicated that with an atmosphere of forming gas (90 per cent. N_2, 10 per cent. H_2) solubility did not change appreciably between 750° and 1250°F. (400° and 675°C.): over this temperature range the average nickel content did not exceed 0·003 per cent. At 1500°F. (815°C.) solubility of the nickel is increased. A limited amount of data indicates that at 1250°F. (675°C.) solubility is greater under an argon atmosphere than under forming gas.

Some study was also made of addition agents designed to inhibit solution and deposition of nickel. Sodium carbonate slightly reduced deposition and is probably not a detrimental impurity in sodium hydroxide used in this connexion. Additions of sodium aluminate markedly reduced solution and deposition of nickel at 1500°F. (815°C.): the optimum concentration of the aluminate was about 10 wt. per cent. There are indications that the thermal conductivity of sodium hydroxide is lowered, or the viscosity is increased, by the aluminate addition.

Corrosion of Nickel-Iron Welds in Caustic Solutions

P. J. GEGNER: 'Corrosion in Caustic of Nickel-Iron Welds Obtained in Fabrication of Nickel-Clad Vessels.'
Corrosion, 1956, vol. 12, June, pp. 261–2.

Field-exposure tests reported in this note indicate that appreciably more iron can be tolerated in the welds of nickel-clad vessels for caustic soda service than has previously been permitted in most specifications.

The tests reported were made in 73 per cent. caustic soda at 250°F. (120°C.) on three types of specimens:—

(1) Nickel specimens made up with nickel weld deposits containing varying amounts of iron (0–23 per cent.).

(2) Solid coupons of nickel-iron alloys containing up to 20 per cent. of iron.

(3) A small test vessel fabricated from $\frac{3}{8}$ in. 5 per cent. nickel-clad steel in which twelve types of nickel and nickel-alloy welds were used. The nine nickel welds in the test vessel contained from 11–38 per cent. of iron.

The results of the tests in series (2), tabulated in the note, show that the corrosion rates were essentially the same in all cases, irrespective of the iron content of the welds or of the solid material. The 5 per cent nickel-clad vessel is reported to have been in service in the 73 per cent. caustic at 250°F. (120°C.) for $3\frac{1}{2}$ years. A nickel weld on it which contained 38 per cent. of iron had visibly corroded, but the remaining welds, containing up to 25 per cent. of iron, showed neither corrosion nor cracking.

The author refers to independent work by The International Nickel Company, Inc., which supports the conclusion that up to 20–25 per cent. of iron does not appreciably affect the rate of corrosion of nickel in caustic solutions. It is therefore concluded that, from the standpoint of corrosion-resistance, iron may be tolerated up to about 25 per cent. Additional work is to be carried out to evaluate the effect of iron on susceptibility of nickel welds to stress-cracking in caustic service.

Potentials of Austenitic Steels in Various Solutions

C. CARIUS: 'Potential-Forming Processes Occurring in Austenitic Chromium-Nickel Steels in Distilled Water and in Neutral Halogen-Salt Solutions.'
Archiv f.d. Eisenhüttenwesen, 1956, vol. 27, May, pp. 323–35.

A study of the course of passivation occurring on three typical commercial grades of austenitic chromium-nickel steel containing molybdenum 0·36–4·65 per cent., by means of measurement of the electrochemical potentials in distilled water, halide solutions and hydrogen-peroxide solutions of varying concentration.

An associated paper by the same author (to be published shortly) will report studies of the electrochemical behaviour of the same steels in 4-*N* sulphuric acid.

Atmospheric Exposure Tests on Stainless Steel

AMER. SOC. TESTING MATERIALS: 'Report of Task Group on Inspection of Nickel-bearing and Non-Nickel-bearing Stainless Steels.'
Contained in Report of A.S.T.M. Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys.
A.S.T.M. Preprint 6, June 1956, pp. 4–6.

Report of third annual inspection of sheet of various grades of stainless steel undergoing long-term atmospheric exposure at Pittsburgh and New York City.

The specimens under test are representative of various grades of straight-chromium and austenitic chromium-nickel steels, and of the new high-manganese low-nickel stainless steel (A.I.S.I. Type 201). Welded, as well as unwelded, specimens are included in the racks.

Resistance of Monel to Corrosion by Chloramine

T. E. LARSON, R. M. KING and L. HENLEY: 'Corrosion of Brass by Chloramine.'
Jnl. Amer. Water Works Assocn., 1956, vol. 48, Jan., pp. 84–8.

Excessive corrosion ('wire drawing') of brass faucet seats in various districts in the U.S.A. was studied in conditions obtaining in water-supply systems of differing types. The results of the tests led to the conclusion that the attack was attributable to the presence of chloramine residuals in parts of the distribution system. Oxygen dissolved in the water did not appear to be a contributory factor. The use of seats of Monel or electrolytically silver-plated brass proved to be a satisfactory solution to the problem.

Corrosion in Borated and Deionized Water

W. K. BOYD and R. S. PEOPLES: 'Corrosion in Borated and Deionized Water at Temperatures up to 500°F.' *U.S. Atomic Energy Commission*, Report BMI-1047, Oct. 14, 1955; 19 pp.

The object of this investigation was to determine the effects of applied stress, contact, and crevices, on the corrosion behaviour, in deionized and borated water, of some of the materials which may be used in construction of reactors. Various stainless steels, beryllium, and representative aluminium alloys were tested at temperatures up to 500°F. (260°C.), in the absence of dissolved gases and in the presence of a 2 : 1 hydrogen : oxygen atmosphere above the liquid.

Fully hardened 17 per cent. chromium steel and precipitation-hardening chromium-nickel-copper steel are shown to be susceptible to stress cracking in borated water at 500°F. (260°C.). Over-ageing the precipitation-hardening steel at 1050°F. (565°C.) eliminated cracking. Straight 18-8 chromium-nickel steel, a low-alloy chromium-manganese-molybdenum steel, and precipitation-hardening chromium-nickel-aluminium stainless steel aged at 1050°F. (565°C.) were the most resistant materials tested. 12 per cent. chromium steel, air-cooled from 1800°F. (980°C.) and tempered at 1600°F. (870°C.) also showed good resistance: its only failure was in borated water at 500°F. (260°C.) under a 2 : 1 hydrogen : oxygen atmosphere.

The aluminium alloys varied very widely in their behaviour: some gave good resistance, others were badly attacked. Couple combinations of straight 18-8 chromium-nickel steel and the precipitation-hardening chromium-nickel-aluminium steel (with and without chromium plating) proved resistant to borated water at 200°F. (93°C.) under a 2 : 1 hydrogen : oxygen atmosphere.

Beryllium coupled to certain types of aluminium alloy and exposed to deionized water at 300°F. (150°C.) under the hydrogen : oxygen atmosphere showed pitting attack in the contact area, as did an aluminium-magnesium alloy when coupled to 18-8 chromium-nickel steel. Uncoupled samples of beryllium did not give good behaviour under the same test conditions.

Corrosion of Stainless Steel in Sulphuric Acid and Nitric-Hydrofluoric Acid Mixtures

R. H. J. GERCKE and D. LEWIS: 'The Dissolution of Zirconium and Corrosion of Stainless Steel in Sulphuric Acid and Nitric-Hydrofluoric Acid Mixtures.' *U.S. Atomic Energy Commission*, Report AECD-3702, Jan., 1954 (Declassified Nov. 14, 1955); 11 pp.

The sulphuric acid used varied in concentration from 86 to 96 wt. per cent., and in the mixed acids the proportions were nitric 50, hydrofluoric 0·10 or nitric 20, hydrofluoric 3·0 wt. per cent.

Zirconium metal is readily dissolved in 90 per cent. sulphuric acid at temperatures of 100°C. or above, and dissolution rates are high in a mixture of 20 per cent. nitric and 3 per cent. hydrofluoric acid at temperatures above 25°C. Chlorimet 2 (nickel-molybdenum-base alloy) was found to show good resistance to 86 per cent. sulphuric acid at 100°C., but was unsatisfactory at 225°C. Durimet 20 (complex nickel - chromium - copper - molybdenum steel) also proved satisfactory at 100°C.

Of the stainless steels tested (representative of straight and molybdenum-containing austenitic nickel-chromium types), only niobium-stabilized 25-12 chromium-nickel steel and Durimet 20 showed good resistance to mixtures of 20 per cent. nitric and 3 per cent. hydrofluoric acid at 30°C.

Corrosion of Nickel by Surface-Active Agents

See abstract on p. 158.

Nickel and Monel Equipment in Fluorine Production

A. J. RUDGE: 'The Present Status of Fluorine Production.'

Chemistry and Industry, 1956, June 16, pp. 504–11.

The paper is based on the progress made, in the period 1934–1955, in the General Chemicals Division of Imperial Chemical Industries, Ltd. Comparison is made between modern fluorine plants in England and in America. *Inter alia*, a report is given of experience with nickel anodes in the I.C.I. plant, and attention is directed to the use, in America, of Monel for cell bodies and diaphragm gauze.

The current stage of development is such that, provided the correct conditions are ensured, fluorine may be prepared with ease and certainty, and the difficulty and hazards of carrying out reactions with it are considerably less than had previously been supposed.

Nickel-containing Materials in Bourdon Pressure Gauges

See abstract on p. 156.

Complex Nickel-base Brazing Alloy

SOC. AUTOMOTIVE ENGINEERS: 'Brazing Alloy: Nickel Base—4 Si, 16·5 Cr, 4 Fe, 3·8 B, Low Carbon.' *A.M.S. Specification* 4776, issued July 1, 1956.

The alloy is to be used primarily for joining corrosion- and heat-resisting alloys in cases where corrosion- and oxidation-resistant joints having good strength at high temperatures are required. It may be used also for production of a corrosion- and oxidation-resistant hard coating.

The following composition is specified:—carbon 0·6 max., silicon 3·0–5·0, chromium 13·0–20·0, nickel+cobalt 65·0–75·0 (cobalt, if determined, 1·0 max.), iron 3·0–5·0, boron 2·75–4·75, per cent.

It is laid down that the solidus shall be not below 1740°F., and the liquidus not higher than 1950°F. The material may be supplied in powder, wire, strip, rod or other form, as ordered.

Nickel-Manganese Brazing Alloys

See abstract on p. 163.

Diffused Coatings of Chromium

R. L. SAMUEL and T. P. HOAR: 'The Influence of Chromium-Diffusion on the Oxidation Properties of Steels, and Nickel- and Cobalt-base Alloys.' *6th International Mechanical Engineering Congress*, June 1956, Paper B/3; 7 pp. + figures.

The advantages of chromium-enrichment of metallic surfaces which are liable to be exposed to oxidizing environments is emphasized, and an outline is given of methods by which chromium can be diffused into the surfaces of various types of material.

A series of experiments is reported in which chromized specimens of steels and non-ferrous alloys were exposed to oxidizing conditions at various temperatures. Behaviour was assessed by periodic weighing, by visual examination to determine the type of oxidation suffered, and by photomicrographic examination, to reveal the nature of the oxidation (e.g., sub-scale formation) and any effects of the exposure on the microstructure of the materials.

The following are among the main conclusions drawn from the observations made:—

Plain Carbon and Low-Alloy Steels, which are not inherently oxidation-resistant, can be considerably protected by a surface layer of chromium-rich alloy, and thereby brought, for oxidation-resisting purposes, to the level of a high-alloy steel.

High-Alloy Steels and Nickel- and Cobalt-base Alloys. Such materials, which have intrinsically much higher oxidation-resistance, can be still further improved in this respect by chromizing, and the nature of the oxidation may thereby be changed, inhibiting, in certain cases, a tendency to intergranular penetration of oxide. Results obtainable in such materials are demonstrated by reference to an austenitic steel containing high percentages of nickel, chromium and cobalt, three nickel-chromium-base alloys containing varying amounts of cobalt and other elements, and two cobalt-base alloys containing nickel, chromium, iron and minor percentages of other constituents.

Adherence of Vitreous Coatings to Stainless Steel

D. G. MOORE and A. G. EUBANKS: 'Influence of Copper Ions on Adherence of Vitreous Coatings to Stainless Steel.'
Nat. Advisory Committee for Aeronautics, Tech. Note 3679, July 30, 1955; 14 pp.

For the past five years there has been in progress, at the National Bureau of Standards, research designed to obtain clearer understanding of the mechanism of ceramic/metal bonding. Reference is directed in this paper to eight earlier reports issued at various stages of the investigation. All of these have been concerned either directly or indirectly with the adherence of vitreous coatings to iron and low-carbon steel. Five of the eight have dealt specifically with the action of 'adherence oxides', an aspect to which particular attention has been given as an aid to developing a general theory of bonding between metals and ceramics.

In the section of the investigation now reported a study was made of the effect of copper oxide in promoting adherence of vitreous coatings to stainless steel of the 18-8 chromium-nickel titanium-stabilized type. It was found that copper ions in the coating produced a significant increase in adherence on both pickled and sand-blasted surfaces of the steel, but that for the pickled specimens the effect of the copper decreased with rise in firing temperature and increased firing time. X-ray examination showed that the copper ions are reduced to metallic copper near the interface during firing, but microscopic examination of sections showed no selective corrosion of the stainless-steel surface. The indications are that in the case of 18-8 stainless steel surface roughness is relatively unimportant with regard to development of a bond between vitreous coatings and the metal.

Specifications for High-Alloy Steels

A. J. TURNELL: 'Stainless and Heat-Resisting Steels. U.S. Specifications and their British Equivalents.' *Welding and Metal Fabrication*, 1956, vol. 24, June, pp. 214-16.

The American Iron and Steel Institute has recently revised its schedule of specifications for stainless and heat-resisting steels, and in this article a comparison is made between the compositions of American types which have been modified and those of the most nearly equivalent British grades, shown in British Standard Specification 1500.

It is pointed out that the changes in the American specifications reflect current conditions in the U.S.A., e.g., removal of Government control from molybdenum, limitation in supply of niobium, and adjustments of nickel contents to secure optimum utilization of restricted quantities available.

Effect of Test Specimen on High-Temperature Mechanical Properties

P. SHAHINIAN and J. R. LANE: 'Effect of Specimen Dimensions on High-Temperature Mechanical Properties.' *Proc. Amer. Soc. Testing Materials*, 1955, vol. 55, pp. 724-30; disc. p. 731.

Since stress-rupture and creep tests are made to obtain design data, due appreciation of any influence of specimen size and shape is important in practical application of test results. Such knowledge is also essential in inter-comparison of values obtained on specimens of varying size and shape.

This paper deals specifically with the influence which such variables may exert on mechanical properties at elevated temperatures. The materials tested were S-816 (cobalt-nickel-chromium-base alloy) and Monel (high-nickel nickel-copper alloy).

In the test specimens used diameters ranged from 0·1785 to 0·505 in. and gauge lengths from 0·25 to 4·0 in. The ratio of length to diameter varied between 0·5 and 16. The tests provided data on time-to-fracture, minimum creep rate, elongation at fracture, and reduction of area, all of which properties were correlated with the dimensions of the specimens. Stress-rupture tests were made at 1500°F. (815°C.)

and 23,000 p.s.i. (10·3 tons per sq. in.) on S-816, and at 1100°F. (593°C.) and 23,000 p.s.i. (10·3 tons per sq. in.) on Monel.

It is shown that, for both alloys, increase in ratio of length to diameter results in shortening time to rupture and lowering total elongation. There was no evidence of any effect of this ratio on the minimum creep rate for Monel, but in S-816 increase in the ratio of length to diameter was accompanied by increase in creep rate. If the ratio of length to diameter is maintained constant the specific effects of changes in cross-sectional area and gauge length are small.

Test for Susceptibility to Intergranular Corrosion

J. V. ALGER, E. C. ROBERTS, R. P. LENT and G. W. ANDERTON: 'All-Glass Multiple-Test Apparatus for Corrosion Testing of Stainless Steels.'
A.S.T.M. Bull., 1956, No. 214, May, pp. 57–60.

The authors describe, with drawings, apparatus in which 60 samples can simultaneously be tested. The procedure is claimed to have many advantages over the single-flask method. A report is given of comparative experiments in which specimens of four steels (extra-low-carbon, niobium-stabilized, and titanium-stabilized types) were tested (*a*) by the standard Huey test as prescribed in A.S.T.M. Recommended Practice A. 262, and (*b*) by the method developed by the authors. Although the results do not show a strictly linear correspondence between the multiple and the single-flask methods of test, the deviations found are stated to be less than those encountered in separately determined Huey tests on any particular set of specimens.

Corrosion- and Heat-Resisting Nickel-Chromium-Iron-Titanium Alloys

SOC. AUTOMOTIVE ENGINEERS: 'Alloy, Corrosion- and Heat-Resistant: Iron Base—20·5 Cr, 32 Ni, 1·1 Ti.'
A.M.S. Specification 5742, issued July 1, 1956.

The specification covers material to be used for parts and assemblies requiring resistance to corrosion and oxidation, and is particularly intended for parts which may require welding during fabrication.

The following composition is laid down: carbon 0·10 max., silicon 1·0 max., manganese 1·5 max., sulphur 0·03 max., chromium 19·0–22·0, nickel+cobalt 30·0–34·0 (cobalt, if determined, 1·0 max.), titanium 0·75–1·5, copper 0·50, per cent., iron remainder.

Analysis of Nickel-Chromium-base Alloys

AMER. SOC. TESTING MATERIALS: 'Proposed Tentative Methods for Chemical Analysis of Nickel-Chromium and Nickel-Chromium-Iron Alloys.'
Contained in Report of Committee E-3 on Chemical Analysis of Metals.
A.S.T.M. Preprint 57, June 1956, pp. 35–9.

The schedule covers methods recommended for photometric determination of manganese (by the periodate procedure) and of copper (by the neo-cuproine procedure).

The alloys to which the methods are applicable fall within the following limits of composition:—nickel 55–80, chromium 15–20, iron 0·5–25, manganese 0·1–4·0, carbon 0·1–0·3, silicon 0·5–2·0, copper 0·005–0·2, sulphur 0·01–0·05, per cent.

Effects of Nuclear Irradiation on Nickel-Chromium Steels

J. C. WILSON and R. G. BERGGREN: 'Effects of Neutron Irradiation in Steel.'
Proc. Amer. Soc. Testing Materials, 1955, vol. 55, pp. 689–707; disc. p. 707.

An introductory review is made of some of the main findings in research already carried out on this subject, by which it has been established that neutron irradiation can markedly alter the mechanical properties of metallic materials. The theoretical aspect of radiation effects is also discussed.

An account is then given of experimental work at two stations of the U.S. Atomic Energy Commission. The mechanical properties of seven typical austenitic nickel-chromium stainless steels and three 0·24 per cent. carbon steels were examined, before and after exposure to irradiation over the range of integrated fast neutron fluxes from 10^{19} to 10^{20} n.v.t. The following are the main conclusions drawn:—

The behaviour of both carbon and stainless steels, in tension and impact, is markedly altered by irradiation.

The tests confirm previous observations that in austenitic steels neutron irradiation may cause increase in hardness, yield strength and tensile strength, while only moderately lowering the ductility.

The stress-strain curves of irradiated austenitic stainless steels are unusual, in that the rate of work-hardening is abnormally low up to a few per cent. elongation, at which point there is an abrupt increase followed by continuous decrease until necking begins.

Yield points were observed in irradiated stainless steels, but the similarity or dissimilarity of this phenomenon with the yield point in carbon steels has not yet been investigated. Yield stress of irradiated stainless steels was shown to be strongly dependent on rate of strain: yield stress increases with strain rate. The tendency of an annealed austenitic stainless steel to show a yield point after irradiation appears to be inversely proportional to the carbon content. (Extra-low-carbon steels, as well as those of normal carbon content, were tested.)

Strain-ageing in austenitic stainless steels may give rise to development of a yield point on subsequent tension testing.

With regard to the carbon steels, the findings of the present authors confirm previous reports of increased tensile and yield stress in normalized, irradiated steels. Reduction of area and uniform elongation are reduced much more drastically by irradiation in the normalized low-carbon than in the austenitic steels: such exposure tends to eliminate the yield point in the unalloyed steels. The ductile-to-brittle transition temperature of normalized carbon steel of the types tested is raised by neutron

irradiation, at a rate which appears to be nearly linear with integrated neutron flux.

Attention is directed to the fact that the data recorded in this paper were obtained at relatively low levels of integrated neutron flux. If metals in future power reactors are exposed to integrated fluxes of 10^{22} or 10^{23} n.v.t., i.e., 100 to 1,000 times greater than that to which the specimens used for these tests were subjected, it is possible that effects not observed at the lower levels may become important.

Effects of Irradiation on Nickel-containing Materials

See abstract on p. 156.

Cleaning of Radio-Contaminated Metals

See abstract on p. 156.

Influence of Compression on Magnetic Properties of Nickel and Nickel Alloys

See abstract on p. 157.

CORRIGENDUM

NICKEL BULLETIN, 1956, vol. 29, No. 7, p. 125.

In Table—

For	Electrical Resistivity—	
	0·141	microhm-cm. at 0°C.
read	6·141	„ „ „

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